THE
JOURNAL
OF THE SOCIETY OF
AUTOMOTIVE ENGINEERS

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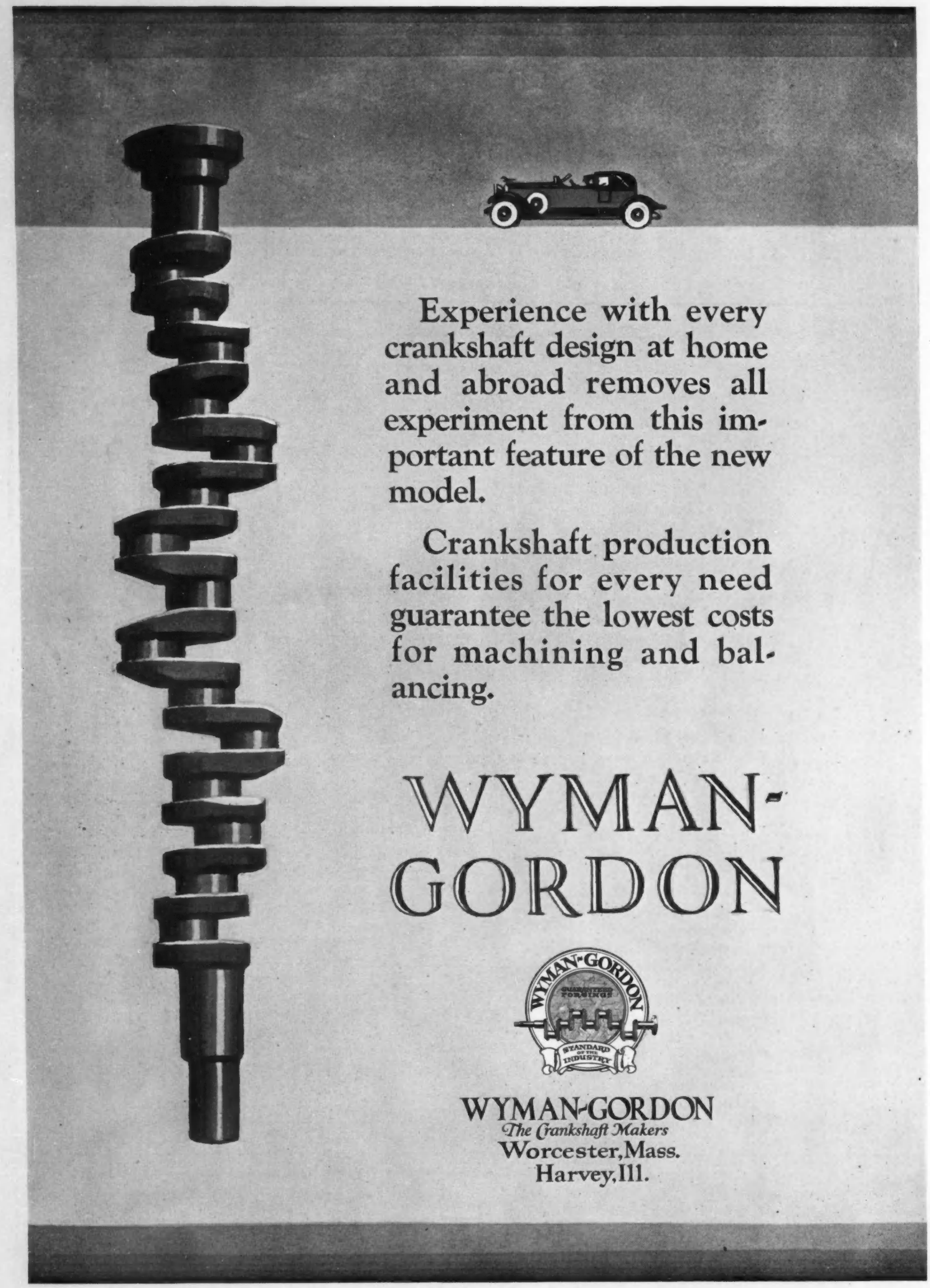
The purpose of meetings of the Society is largely to provide a forum for the presentation of straightforward and frank discussion. Discussion of this kind is encouraged. However, owing to the nature of the Society as an organization, it cannot be responsible for statements or opinions advanced in papers or in discussions at its meetings. The Constitution of the Society has long contained a provision to this effect.


Experience with every crankshaft design at home and abroad removes all experiment from this important feature of the new model.
Crankshaft production facilities for every need guarantee the lowest costs for machining and balancing.
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THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

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Chronicle and Comment

Uniform State Laws Needed

IN the Semi-Annual Meeting paper, Effects of Legislation on Design of Automotive Vehicles, printed in this issue of THE JOURNAL on p. 49, the authors point to the need for uniform or standardized interstate laws. They feature the many industrial organizations striving to bring the light of fact and reason to bear upon the problems of motor-vehicle regulation.

The following statement should stimulate action for the welfare of the automotive industry:

> These bodies are representative and demand the efforts of earnest, unselfish and enlightened workers. They cannot carry the load alone. They require the cooperation and assistance of individuals such as make up the membership of the Society of Automotive Engineers.

Tenth Anniversary of The Journal

WITH the July, 1927, issue, THE JOURNAL celebrates its tenth anniversary, the present form of publication having been initiated with the July, 1917, issue. The older members of the Society will remember that the Society's monthly publication from April, 1911, to July, 1917, was the S.A.E. BULLETIN. The present form of publication was necessary owing to the greater activity of the Society and the resulting need for more suitable means of publishing the papers presented at the National and the Sections Meetings.

During the last 10 years, the character of THE JOURNAL has changed very little, which speaks well for the style and typographical standards established for it in 1917. Chronicle and Comment was started as a regular feature of THE JOURNAL in May, 1922. In 1923, a news department was established to report the current activities of the Sections of the Society, with brief summaries of the papers and discussions presented. Standardization Activities was started as a department in 1921, Automotive Research in 1922, and Production Engineering and Operation and Maintenance in May, 1927, all of these, together with the news stories of the National Meetings, now being a part of the News Section. As evidenced in recent issues of THE JOURNAL, efforts are being made to obtain a more attractive appearance by the use of a certain amount of art work.

THE JOURNAL is still faced with the problem of printing the large number of papers presented at National and Sections Meetings. Efforts are being made to balance this material in proportion to the number of members interested in the different fields of automotive engineering.

The contents and form of THE JOURNAL necessarily represent the consensus of opinion of the Society members. The Publication Committee appreciates the constructive criticism that it has received in past years and looks forward to the continuing help of the members.

Automotive Ordnance

MAJOR-GEN. C. C. WILLIAMS, the Chief of Ordnance, has for many years administered the wise policy of maintaining, through Ordnance Department officers, contact with industrial progress in the development of automotive apparatus. The Society has, in furtherance of this movement, had from year to year an Ordnance Advisory Committee, of which First Vice-President Wall is now the Chairman, Past-President Alden having served as its Chairman for several years. The sixteenth meeting of the Committee in conference with Army officers was held at Detroit last month. The representatives of the Ordnance Department in attendance were Col. W. H. Tschappat, Major L. H. Campbell, Jr., Major W. A. Capron, Major B. O. Lewis, Major J. B. Rose, Capt. J. K. Christmas, W. F. Beasley and H. A. Knox. The following of the Society's Ordnance Advisory Committee were present: Chairman W. G. Wall; Past-Presidents H. W. Alden, B. B. Bachman and C. M. Manly; A. F. Masury, Dent Parrett, G. A. Round, and William Turnbull. The additional members of the Committee are A. W. S. Herrington and W. L. Batt.

President Hunt received the delegation prior to their making a visit to the Research Laboratory and the Proving Ground of the General Motors Corporation. In addition to these inspection trips and discussion of the list of business of the meeting, the party was hospitably received at plants of the Ford Motor Co.

Classification for Notes and Reviews

THE items appearing in Notes and Reviews, which has been published regularly as a department of THE JOURNAL, will, beginning with this issue, be arranged in a fixed order according to their subject-matter and bear a designation of letter and number to denote the nature of their contents. These two innovations are being made with the purpose of assisting readers to find easily the type of article in which they are interested

and to maintain an organized file of the abstracts that cover in so far as possible the more important current publications in the automotive field.

The system used will be that developed for the purpose of classifying members of the Society according to their interests in the industry. The 13 main divisions represent for the most part products, and the 6 sub-divisions, functions. The articles will be grouped together according to divisions; each division being preceded by the suitable class-heading. Within each division, the articles are arranged according to a certain fixed order of subdivision. The title of each article will be followed by a letter and number designation in brackets, the letter representing the division and the number the sub-division. The divisions and subdivisions in the order in which they will be used, together with their corresponding letters and numbers, are as follows:

Divisions.—A, Aircraft; B, Body; C, Chassis Parts; D, Education; E, Engine; F, Highway; G, Material; H, Miscellaneous; I, Motorboat; J, Motorcoach; K, Motor-Truck; L, Passenger-Car; and M, Tractor.

Subdivisions.—1, Design and Research; 2, Maintenance and Service; 3, Miscellaneous; 4, Operation; 5, Production; and 6, Sales.

Transactions

MEMBERS will recall that, beginning with Part I of the 1923 TRANSACTIONS, a nominal charge of $2 per Part was established by the Council, in view of the fact that it had become clear that many members did not care to have in bound TRANSACTIONS form the various papers and discussions and other matter that had appeared a relatively long time before in THE JOURNAL. That is, it was considered that the wastage element should be reduced as much as possible, the members still being afforded opportunity to secure TRANSACTIONS by placing orders for the succeeding Parts as issued.

Prior to establishing the price of $2 per Part, the practice for a while was to send the TRANSACTIONS to members who specially requested copies, without payment in addition to regular dues; the practice of distributing TRANSACTIONS to all members without extra cost having been discontinued. One rather striking fact at the time the members were asked to pay $2 per Part was that more copies were ordered than had been requested under the distribution-without-extra-cost method. Four hundred and thirty-seven copies of Part II, 1922, were requested by members, whereas 651 copies of Part I, 1923, were ordered by members at $2 per Part. Thereafter there was a steady decrease in the number of Parts ordered until the time of the issuance of Part II of 1925 TRANSACTIONS, 633 copies of this Part having been ordered.

The present method of distributing the TRANSACTIONS has appeared to be somewhat unsatisfactory. That is, although members can place standing orders for Parts of TRANSACTIONS as issued, there has been confusion in some members' minds as to whether they had placed orders for all Parts they wished. Accordingly, the Council at its last meeting directed that in the future members shall be billed for TRANSACTIONS in substantially the same manner in which they are billed for Section dues in connection with the collecting of Society dues. That is, the members in general will be informed that if they wish to receive Parts of the TRANSACTIONS to be issued during a given fiscal year, they should remit for these at the time of paying the dues.

Technical Papers

THE Meetings Committee is now planning the programs for the Aeronautic, the Production and the Transportation Meetings of the Society. The time and place of the Aeronautic Meeting have not been definitely decided upon. The original idea was to schedule the meeting for the time and place of the National Air Races, but, as it has been decided to hold these races at Spokane, Wash., in September, where it would be impossible for most of the members to attend, an Eastern place for the Aeronautic Meeting will be selected shortly. The Production Meeting will convene in Cleveland on Sept. 19 and 20 and be continued in Detroit on Sept. 21 and 22. The Transportation Meeting will be held in Chicago early in November.

As stated in the report of the Meetings Committee at the Business Session of the Summer Meeting, the Committee is governed very largely in outlining technical programs by suggestions received from members of the Society in the form of answers to questionnaires, as well as by comment on definite proposals and by personal contact with leading engineers. It should be understood clearly that the Committee welcomes suggestions as to subjects and possible authors. Only through the splendid cooperation of the members in this connection has the Meetings Committee been able in the past to arrange for technical sessions that warrant the time and expense of the members of the Society in attending the National meetings.

The responsibility for the helpfulness and success of the Aeronautic, the Transportation and the Production Meetings rests very largely on the members of the Society who specialize in these respective fields of the automotive industry.

Recommendations of members as to what technical papers should be secured also enable the Meetings Committee to assist the Papers Committees of the various Sections in their work. In connection with production papers, the Production Advisory Committee has appointed John Younger to cooperate with the Sections, through the Sections Committee, in obtaining production data and articles. It is recognized that there have not been enough production engineering papers in THE JOURNAL.

Wide World Photos

Lindbergh: Sans peur et sans reproche,
Flier of oceans on a sandwich,
Exemplar of young manhood,
Interpreter and dramatizer par excellence of aviation and aircraft,
A lone eagle, duty enthralled, he flew across the sky.

Standardization Activities

REPORT ON MATHEMATICAL SYMBOLS

Subcommittee Urges Uniform Practice for Engineering Signs and Abbreviations

Prof. Robert M. Anderson, who is the Society's representative on the Sectional Committee on Scientific and Engineering Symbols and Abbreviations that was organized under the procedure of the American Engineering Standards Committee, has transmitted from the Mathematical Symbols Subcommittee the following report which is in process for adoption as an American Standard. It is now before the Sectional Committee for letter-ballot preparatory to final approval by the sponsors and the American Engineering Standards Committee. Although the substance of the report will be of direct interest principally to mathematicians, authors of mathematical papers and books and mathematical engineers, it is of importance to the Society as a matter of standardization of symbols and abbreviations and of mathematical papers published in THE JOURNAL. The adoption and use of the symbols should do much to relieve those who use them of the inconvenience and loss of time required to translate different symbols into corresponding terms or into such terms as they may have been accustomed to use.

It has been stated that at present there is a noticeable tendency abroad toward a more varied use of symbols and abbreviations and the introduction of many new ones. General use of a uniform practice in this Country might conceivably have a stabilizing effect due to increasing international intercourse in engineering and commerce.

The report of the Subcommittee follows.

ARITHMETIC AND ALGEBRA

1.1 $= + - \pm \mp < > \leqq \geqq$ ( ) [ ] % ∞ $\approx$ for approximately equal to

1.2 $a \times b = a \cdot b = ab$; $a \div b = a/b = \frac{a}{b}$. Influence extends to next + or = Thus, $a - b/c - d$ should not be used for $(a-b)/(c-d)$. Note that $\frac{a}{b}$ is difficult to print in running text.

1.3 $a/b = c/d$ for proportion. Discourage $a:b::c:d$

1.4 Notation by powers of 10 for very large or very small numbers is recommended; as 3.140×10^3 and 3.140×10^{-3}. The notation 0.0^3314 is useful in tables, to indicate that there are five zeros after the decimal point.

1.5 In writing numbers having a large number of digits, half-spaces instead of commas should be used to separate groups of digits. In writing decimals, the 0 before the decimal point should not be omitted except in tables.

1.6 $|x|$ = absolute value of x. $x! = 1 \cdot 2 \cdot 3 \cdots x$. Discourage $\underline{x|}$

1.7 $\sqrt{\ } x = + \sqrt{\ } x$, not $\pm \sqrt{\ } x$ (x being real and positive).

$a^{1/n} = \sqrt[n]{\ } a$. $a^{-n} = 1/a^n$. $\exp x = e^x$ is useful when x is a complicated expression. Note that the bar or vinculum after the $\sqrt{\ }$ is very expensive to print.

1.8 When $\log x$ is ambiguous, use $\log_{10} x$ *or* $\log_e x$. The notation $\ln x$ may be mentioned as an alternative for $\log_e x$.

1.9 $P(n,r) = n(n-1)(n-2) \ldots (n-r+1)$
$C(n,r) = [n(n-1)(n-2) \ldots (n-r+1)]/[1.2.3 \ldots r]$ = binomial coefficients. A common alternative for $C(n,r)$ is $(\frac{n}{r})$; this, however, is difficult to print in running text.

1.10 $a \propto b$ meaning a varies directly as b

ELEMENTARY GEOMETRY

2.1 $\angle\ \triangle\ \parallel\ \perp\ \odot\ \square\ \therefore$

ANALYTIC GEOMETRY

3.1 x, y, z; ξ, η, ζ; rectangular coordinates. Right-handed system preferred.

3.2 ρ, s = intrinsic coordinates. ρ = radius of curvature, s = length of arc.

3.3 $l = \cos \alpha$, $m = \cos \beta$, $n = \cos \gamma$, direction cosines.

3.4 r, Θ = polar coordinates. ψ = angle from radius vector to tangent.

3.5 r, Θ, ϕ = spherical coordinates. Θ = co-latitude, ϕ = longitude. Usage general in mathematical physics; other notations are used in astronomy.

3.6 r, Θ, z = cylindrical coordinates. Usage diverse.

3.7 Conics: e = eccentricity.
p = semi-latus rectum. Usage general in U. S.

3.8 Straight line $y = mx + b$

TRIGONOMETRIC AND HYPERBOLIC FUNCTIONS

4.1 ° ′ ″ $\sin x$, $\cos x$, $\tan x$, $\operatorname{ctn} x$, $\sec x$, $\csc x$.

4.2 $\sin^{-1} x$ = the principal value of the angle whose sine is x, when x is real. Thus, $-\pi/2 \leqq \sin^{-1} x \leqq \pi/2$, $0 \leqq \cos^{-1} x \leqq \pi$, $-\pi/2 \leqq \tan^{-1} x \leqq \pi/2$. Discourage arc $\sin x$.

4.3 $\sin^2 x$ for $(\sin x)^2$ is an exceptional notation, justified by usage.

4.4 $\sinh x$, $\cosh x$, $\tanh x$, $\operatorname{ctnh} x$, $\operatorname{sech} x$, $\operatorname{csch} x$.

4.5 $\cosh^{-1} x$ = the principal value (when x is real). Discourage arc $\sinh x$.

4.6 $\sinh^2 x$ for $(\sinh x)^2$ is an exceptional notation, justified by usage.

4.7 In general f^{-1} means the inverse of the function f; while f^2 denotes iteration of the functional operation. But in exceptional cases, f^2 may denote the square of the function f (as in $\sin^2 x$ and $\sinh^2 x$). In general, $[f(x)]^{-1} = 1/f(x)$.

CALCULUS

5.1 If $y = f(x)$, derivative $= y' = f'(x) = \frac{dy}{dx} = D_x y$.

Second derivative $= y'' = f''(x) = \frac{d(y')}{dx} = D_x^2 y = \frac{d^2y}{dx^2}$

Note $\frac{d^2y}{dx^2}$ cannot be regarded as a fraction, except when x is the independent variable; in general, $\frac{d^2}{dx^2} = D_x^2$ = a symbol of operation on y.

5.2 If $u = f(x,y)$, partial derivative $= u_x = f_x(x,y) = D_x u = \frac{\partial u}{\partial x}$

Similarly, $u_{xy} = f_{xy}(x,y) = D_y(D_x u) = \frac{\partial^2 u}{\partial y \partial x}$

Note. $\frac{\partial^2 u}{\partial y \partial x}$ and $\frac{\partial u}{\partial x}$ are not fractions; $\frac{\partial}{\partial x} = D_x$ and $\frac{\partial^2}{\partial y \partial x} = D_y D_x$ are symbols of operation.

5.3 Δy = increment, dy = differential, δy = variation, $\overset{b}{\underset{i=a}{\Sigma}}$ signifies summation.

5.4 $\dot{x} = dx/dt = v$; $\ddot{x} = dv/dt$. Used only for differentiation with respect to the time t, and difficult to print.

5.5 $\lim\limits_{x \to a} (y) = b$; $y \to b$ as $x \to a$. Discourage $\doteq$.

5.6 $\int_a^b f(x)\,dx$. $F(x) \Big/_a^b = F(b) - F(a)$

$$\int\int f(x)\,dx\,dy = \int\Big[\int\Big/ f(x,y)\,dx\Big]dy.$$

5.7 $\pi = 3.1416 \ldots$ $e = 2.718 \ldots$ $i = \sqrt{-1}$. In pure mathematics.

5.8 If $z = x + iy$, then $|z|$ = absolute value, or magnitude, $\angle z$ = angle. $R(z)$ and $I(z)$ = real and imaginary parts, $\bar{z}$ = conjugate of z. Where $\bar{z}$ is difficult to print, use conj. z.

Special Functions

6.1 *Bessel Functions.*—The notation used in G. N. Watson's Treatise, 1922, as indorsed by E. P. Adams in the Smithsonian tables, 1922, is recommended.

6.2 *Bernoulli numbers.*—Of the five or six different notations in use, the notation B_1, B_3, B_5, ... has historical priority and many practical advantages, but the notation B_1, B_2, B_3 . . . is the one most used in recent years. To indicate what usage is being followed, authors will do well to state explicitly the value of the first few numbers, as $B_1 = 1/6$, $B_2 = 1/30$, $B_3 = 1/42$. . . .

6.3 $\gamma = 0.5772\ldots$ Euler's constant.

Vector Analysis

7.1 Vectors to be indicated in printed matter by letters in bold face type, and in written manuscript by letters modified by a bar above or by the doubling of some part of the character. The magnitude of a vector to be indicated in print by the corresponding italic letter, and in manuscript when necessary by the use of the absolute value signs, $|\ |$.

7.2 The scalar product, or dot product, $= a \cdot b$, the dot being centered. Other notations are Sab, or (ab) in round parentheses.

7.3 The vector product, or cross product, $= a \times b$, the cross being small. Other notations are Vab, or $[ab]$ in square brackets.

7.4 i, j, k = unit vectors along the axes, right-handed system.

7.5 As to further questions of notation in vector analysis, including tensor analysis, the Subcommittee recognizes the desirability of a thoroughgoing attempt to bring uniformity out of the present diversity of usage, but recommends the appointment of a special committee to take up this subject.

Abbreviations

8.1 It is desirable to distinguish between (*a*) a "symbol", that is, a single letter or a single letter affected with subscripts, etc., which is to be used to represent a numerical value in a formula; and (*b*) an "abbreviation", which may consist of several letters, but is not intended to be substituted for a numerical quantity in a formula.

8.2 Standard abbreviations such as ft./sec.^{2}, ft-lb./min., etc., should not be further condensed, lest clearness be sacrificed to brevity.

Note.—The recommendations concerning terms and symbols in elementary mathematics contained in Chapter 8, p. 74, of the Report on the Re-Organization of Mathematics in Secondary Education, made in 1923 by the National Committee on Mathematical Requirements, under the auspices of the Mathematical Association of America, were, with one or two unimportant exceptions, endorsed by the Subcommittee.

FEWER BALL-BEARING SIZES

Reduction of Number in Use Advocated as Being an Advantage to Purchasers

About 1 year ago the manufacturers of radial ball-bearings listed the sizes of the radial, the extra-wide, the angular-contact and the separable types of ball bearing on a

LIST OF PREFERRED SIZES OF BALL BEARING—S.A.E. NUMBERS

Bore, Mm.	Annular Type Light	Annular Type Medium	Annular Type Heavy	Extra-Wide Type Light	Extra-Wide Type Medium	Extra-Wide Type Heavy	Angular-Contact Light	Angular-Contact Medium	Angular-Contact Heavy	Extra-Small	Separable
4										34	
5											5
6										36	
8										38	8
9										39	
10	200			5200			7200				10
12	201			5201			7201				12
13											13
15	202	302		5202	5302		7202	7302			15
16											16
17	203	303		5203	5303		7203	7303			17
20	204	304		5204	5304		7204	7304			
25	205	305	405	5205	5305	5405	7205	7305	7405		
30	206	306	406	5206	5306	5406	7206	7306	7406		
35	207	307	407	5207	5307	5407	7207	7307	7407		
40	208	308	408	5208	5308	5408	7208	7308	7408		
45	209	309	409	5209	5309	5409	7209	7309	7409		
50	210	310	410	5210	5310	5410	7210	7310	7410		
55	211	311	411	5211	5311	5411	7211	7311	7411		
60	212	312	412	5212	5312	5412	7212	7312	7412		
65	213	313	413	5213	5313	5413	7213	7313	7413		
70	214	314	414	5214	5314	5414	7214	7314	7414		
75		315	415		5315	5415		7315	7415		
80		316	416		5316	5416		7316	7416		
85		317	417		5317	5417		7317	7417		
90		318	418		5318	5418		7318	7418		
100		320			5320			7320			
110		322			5322			7322			
120		324[a]									
130		326[a]									
140		328[a]									
150		330[a]									
160		332[a]									
180		336[a]									
200		340[a]									

[a] These sizes are considered beyond the range of usual automotive sizes of ball bearing and are not included in the S.A.E Handbook. Their dimensions can be secured from the Society upon request.

basis of large-quantity production as indicated by study of their sales statistics. It was felt that by making it generally known which sizes of bearing are in most extensive use, many consumers could be guided by such a list in the selection of sizes that would enable them to draw from quantity production and thus gain the advantage of quicker deliveries from stock and eventually to secure the advantage of whatever reduction in costs the bearing manufacturers can make.

At a recent meeting of bearing manufacturers, as represented on the S.A.E. Ball and Roller-Bearings Division and the Sectional Committee on the Standardization of Ball Bearings, it was stated that several of the manufacturers have indicated the selected sizes in their catalogs and that it would be helpful to publish this list again to bring it to the attention of the automotive industry generally. The list on p. 5 shows the standard numbers of the bearing sizes under their respective headings. The detail dimensions for these bearings are given in the March, 1927, issue of the S.A.E. HANDBOOK, commencing on p. C25. Copies of the HANDBOOK or, if preferred, the individual tables of bearings, can be obtained from the Society's offices in New York City.

ROUND UNSLOTTED-HEAD BOLTS

Survey Made To Determine Types and Quantities Used by Automotive Industry

The Society, as one of the sponsors of the Sectional Committee on Round Unslotted-Head Bolts, recently approved a report as a Tentative American Standard for Step Bolts, Ribbed Carriage-Bolts, Square-Neck Carriage-Bolts, Countersunk Carriage-Bolts, Fin-Neck Carriage-Bolts, and Button-Head Machine-Bolts.

The question has been raised as to the possibility of adopting as an S.A.E. Specification part or all of this report. The decision rests largely on the extent to which the various types and sizes are used in the automotive industry. To determine this information, a copy of the complete Tentative American Standard showing dimensions of all types has been forwarded to motor-truck, motorcoach, tractor, body, and passenger-car builders requesting that they check the sizes they use and furnish figures indicating their approximate annual consumption. No consideration is being given to the lengths of the various sizes as it is not believed possible to standardize on this particular dimension due to the great variance in the requirements of users.

Excellent cooperation has been received in compiling this information and it is anticipated that some definite action can be taken by the Parts and Fittings Division at its first meeting in the fall.

TESTS ON DECK MATERIAL UNDERTAKEN

Manufacturers Cooperate in Determining Tensile-Strength Test Specifications

In an effort to determine tensile-strength specifications for various leather substitutes, tests on samples of upholstery-leather substitutes were conducted by the laboratories of several manufacturers of this product. No definite recommendation has as yet come from the results of these tests, inasmuch as it was thought advisable to carry further the tests on other leather substitutes before definitely recommending a method of testing and set tensile-strength specifications for various materials.

As a result, samples of single and double-texture deck-material were submitted to the Subdivision on Upholstery-Leather Substitutes by six manufacturers and test pieces were cut from each sample. These test pieces, numbered so as not to disclose the identity of the makers, were then forwarded to each of the six manufacturers and to the Bureau of Standards for conducting tests by the grab method to determine the tensile-strength of the materials.

The results, when tabulated, will provide a set of figures from which it should be possible to determine tensile-strength specifications. A similar procedure was followed previously on the upholstery-leather substitutes and it is hoped that the Subdivision will be able to present to the Passenger-Car Division figures which, if approved, will be of assistance to the buyers of these two classes of material.

STANDARDS APPROVED BY LETTER-BALLOT

The recommendations of the several Divisions of the Standards Committee that were presented and approved at the Society's Semi-Annual Meeting at French Lick Springs, Ind., in May were submitted to letter-ballot of the voting members for final approval, the ballot being counted on June 25 with the results as given below:

	Yes	*No*	*Not Voting*	*Blank*
BALL AND ROLLER BEARINGS DIVISION				
Taper Roller Bearings[1]	216	0	77	44
ELECTRICAL EQUIPMENT DIVISION				
Automobile Wiring	238	0	79	20
Distributor Nipples	238	0	82	17
Dome-Light Lamp Sockets	238	0	78	21
Instrument Mountings and Connections	241	1	78	17
Nomenclature	228	0	90	19
Passenger-Car Body-Lighting Switches	235	0	85	17
IRON AND STEEL DIVISION				
Heat-Treatment Definitions	270	1	51	15
Numbering of Steels (Sectional Committee Report)	256	1	65	15
S.A.E. Steel 1046	262	1	59	16
S.A.E. Steel 2512 Changes	266	2	54	15
S.A.E. Steels 3415, 3435 and 3450	266	0	56	15
S.A.E. Steel 4615 Changes	265	1	56	15
MOTORCOACH DIVISION				
Turning Radius	214	2	92	29
PARTS AND FITTINGS DIVISION				
Bumper Heights and Lengths	236	2	73	26
Flexible-Disc Tolerances	236	0	74	27
Oilless-Bushing Specifications	249	1	58	26
Small Rivets (Sectional Committee Report)	237	1	73	26
Split and Tubular Rivets	239	2	70	26
PRODUCTION DIVISION				
Taps, Cut and Ground-Thread	233	2	74	28

[1] The provisional approval by the Standards Committee of the supplementary report on rolled bearings has been confirmed by a nearly complete vote of the Ball and Roller Bearings Division, no negative ballots being cast.

The new standards approved for adoption and the revisions of the present standards will be included in the September, 1927, issue of the S.A.E. HANDBOOK that will probably be mailed to the members about the second week in September.

The standard for taps for cut and ground-threads which has been classed as a Production standard will be referred to in the S.A.E. HANDBOOK, but the specification itself, as printed in the May issue of THE JOURNAL, will be issued on a separate 8½ x 11-in. leaflet to conform to the other Production standards that are being issued by the Society.

Production Engineering

DEVELOPING STANDARD ACME THREADS

Mathematical Comparisons by Earle Buckingham of Chased and Milled Threads

An important contribution to the practice of cutting screw-threads has been made by Earle Buckingham, who is one of the Society's representatives on the National Screw Thread Commission, in his treatise entitled Profile of Acme Threads, that supplements much of the work that has been done by both the Commission and the Sectional Committee for the Standardization of Screw-Threads which was organized under the sponsorship of the Society and the American Society of Mechanical Engineers in 1920.

Profile of Acme Threads

A screw-thread chased in a lathe with a flat-topped tool set square with the axis of the thread and on line with the axis of the thread will have a form in the axial section of the screw-thread identical with that of the cutting edges of the tool. When such a tool is tipped to the helix angle of the screw-thread, or the thread is cut with a milling-cutter, the axial section of the screw-thread is no longer a reproduction of the form of the cutting edges of the tool because of the side-cutting conditions introduced by the varying helix-angles at the different diameters and the foreshortening effect of tipping the tool. This difference in form becomes greater as the helix angles increase.

Consideration is being given at this time to the standardization of Acme thread forms and practice in their design and production. Such standardization, to be effective, must lend itself to production by any of the commonly used methods.

One question is whether the form of the axial section or that of a normal section should be constant or standard. This does not make so much difference when the helix angles are small but becomes of increasing importance as the helix angles are increased. Mathematically, the axial section is the easiest to study. In many cases, however, the normal section is the easiest to measure. In either case, it will be found that, to maintain a constant form with the higher helix-angles, special cutting tools will be required in each appreciably different case.

The purpose of this discussion is to point out the conditions that result from cutting such threads with a chasing-tool tipped to the helix-angle and with a milling-cutter. It will deal only with the axial sections of the screw-threads so produced.

CHASING ACME THREADS

When a thread is chased in a lathe with a flat-topped tool set on the center-line of the lathe spindle, the continuation of the straight cutting-edges intersects the axis of the screw-thread. The screw-thread surface thus formed by such a generatrix has a straight-line form in the axial section. When this tool is tipped, however, the continuation of the straight cutting-edge no longer intersects the axis of the screw but is tangent to a cylinder that is concentric with the screw-thread. If the vertical position of this tool is such that the intersection of the continuations of the two cutting edges is on a line with the axis of the screw, both sides of the thread will be symmetrical and the continuation of both cutting edges will be tangent to opposite sides of the same cylinder. If this intersection is not in this line, on account of the vertical setting of the tool or of the rake on the top of the tool, the two sides of the thread will be unsymmetrical and the continuation of one cutting edge will be tangent to a smaller cylinder than that to which the second is tangent.

Fig. 1 shows a flat-topped tool tipped to the helix angle of the screw-thread. Thus, when

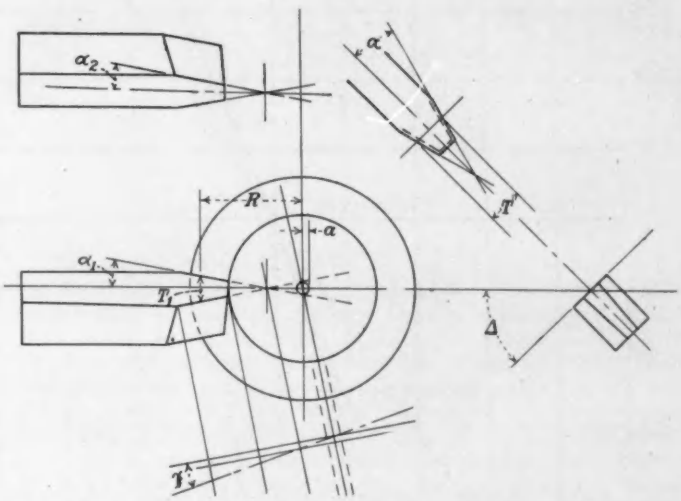

FIG. 1—FLAT-TOPPED TOOL TIPPED TO THE HELIX ANGLE OF THE SCREW-THREAD

a = radius of cylinder to which continuation of straight cutting-edges are tangent
α = angle of edge of chasing tool
α_1 = angle of projection of cutting edge in a plane perpendicular to axis of screw or the end elevation
α_2 = angle of projection of cutting edge in plan view
Δ = helix angle, or angle from horizontal at which top of flat tool is set
γ = angle between generatrix and plane perpendicular to the axis of the screw
R = radius from axis of screw to thickness T
T = thickness of tool at any given distance from the point or intersection of cutting edges

Then

$$\tan \alpha_1 = \tan \alpha \sin\Delta$$
$$T_1 = T \sin \Delta$$
$$a = [R\ (T_1/2 \tan \alpha_1)] \sin \alpha_1$$
$$\tan \alpha_2 = \tan \alpha \cos \Delta$$
$$\tan \gamma = \tan \alpha_2 \cos \alpha_1 = \tan \alpha \cos \Delta \cos \alpha_1$$

The profile of the axial section of such a screw-thread form is given by the following equation:

$$x = [\tan \gamma \sqrt{(y^2 - a^2)}]\ [(L/2\pi) \text{ arc tan} \sqrt{([y^2/a^2] - 1)}]$$

where

L = lead of screw
x = distance along axis of screw
y = radius of any point on screw-thread surface

The equation of the tangent to this form is as follows:

$$\tan \phi = D_x y$$
$$= [2\pi y \sqrt{(y^2 - a^2)}] \div [2\pi y^2 \tan \sqrt{} - aL]$$

As a definite example, an Acme screw-thread, 2-in. outside-diameter, 1-in. pitch, 4-start thread, with a lead of 4 in. is taken to determine the coordinates to which to plot its form in the axial section. This gives the following values:

$$\alpha = 14 \text{ deg. } 30 \text{ min.}$$
$$R = 0.75$$
$$L = 4.00$$
$$T = 0.50$$
$$\tan \Delta = L/2\pi R = 4.0000/4.7124 = 0.84882$$
$$\Delta = 40 \text{ deg. } 19 \text{ min. } 30 \text{ sec.}$$
$$\tan \alpha_1 = 0.25862 \times 0.64712 = 0.16736$$
$$\alpha_1 = 9 \text{ deg. } 30 \text{ min.}$$
$$T_1 = 0.50000 \times 0.64712 = 0.32356$$
$$a = [0.75000\ \ (0.32356/[2 \times 0.16736])]\ 0.16505$$
$$= 0.03576$$

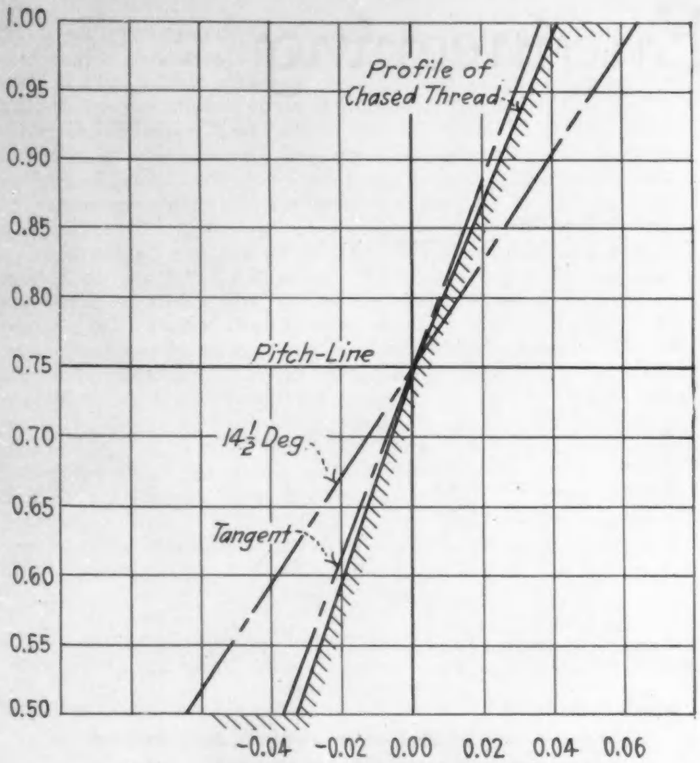

FIG. 2—AXIAL SECTION OF THE CHASED THREAD

$$\tan \gamma = 0.25862 \times 0.76239 \times 0.98629$$
$$= 0.19447$$
$$\gamma = 11 \text{ deg. } 0 \text{ min. } 20 \text{ sec.}$$

Solving the equation of the profile for the following values of y, the tabulated coordinates are

y	x	$(x + 0.82384)$
0.50000	—0.85747	— 0.03363
0.55000	— 0.85185	— 0.02801
0.60000	— 0.84556	— 0.02172
0.65000	— 0.83876	— 0.01492
0.70000	— 0.83152	— 0.00768
0.75000	— 0.82384	0.00000
0.80000	— 0.81613	0.00771
0.85000	— 0.80806	0.01578
0.90000	— 0.79981	0.02403
0.95000	— 0.79141	0.03243
1.00000	— 0.78287	0.04097

The tangent to this form at the pitch radius of 0.75 in. is as follows:

$$\tan \phi = 6.48615$$
$$\phi = 81 \text{ deg. } 14 \text{ min. } 10 \text{ sec.}$$

This form is plotted to a distorted scale in the direction of x in Fig. 2. A line representing the 14½-deg. profile is also shown in this figure. It will be noted that the flank of this chased thread is convex, and that the tangent to this form at the pitch-line measured from a perpendicular to the axis of the thread is much less than the basic form. In this case this angle has been reduced to 8 deg. 45 min. 50 sec.

MILLING ACME THREADS

The profile of a milled thread in the axial section will vary as the diameters of the screw-thread and milling-cutter vary. An exact mathematical solution for any diameter of cutter would be very complex, so that consideration will be given to only one limiting case where the solution is relatively simple. This will be when the diameter of the cutter is infinitely large and will show greater distortion in the milled profile than actually exists. In this case also the generatrix will not pass through the axis of the screw but will be tangent to a cylinder as before. Thus when

a = radius of cylinder to which generatrix is tangent
α = angle of cutting edge of milling cutter
$\triangle$ = helix angle at which cutter is set
γ = angle between generatrix and plane perpendicular to the axis of the screw
L = lead of screw
R = radius of screw, pitch radius, where helix angle is equal to $\triangle$

$$\cos \gamma = \cos \alpha \cos \triangle$$
$$a = L/2\pi \tan \gamma$$
$$\tan \triangle = L/2\pi R$$

The same equations for the profile of the axial section and its tangent as before apply here also. Due to the fact that the angle of the generatrix in this case is the same as the helix angle on the base cylinder, these equations can be simplified somewhat if desired.

As a definite example the same Acme screw will be considered as before. This gives the following values:

$$\alpha = 14 \text{ deg. } 30 \text{ min.}$$
$$R = 0.75000$$
$$L = 4.00000$$
$$\tan \triangle = 0.84882$$
$$\triangle = 40 \text{ deg. } 19 \text{ min. } 30 \text{ sec.}$$
$$\cos \gamma = 0.73810$$
$$\gamma = 42 \text{ deg. } 25 \text{ min. } 50 \text{ sec.}$$
$$\tan \gamma = 0.91407$$
$$a = 0.69647$$

Solving the equation for the profile as before, the following coordinates are obtained

y	x	$(x - 0.01237)$
0.50000	undercut	undercut
0.55000	undercut	undercut
0.60000	undercut	undercut
0.65000	undercut	undercut
0.70000	0.00022	— 0.01215
0.75000	0.01237	0
0.80000	0.03231	0.01994
0.85000	0.05676	0.04439
0.90000	0.08439	0.07202
0.95000	0.11445	0.10208
1.00000	0.14641	0.13404

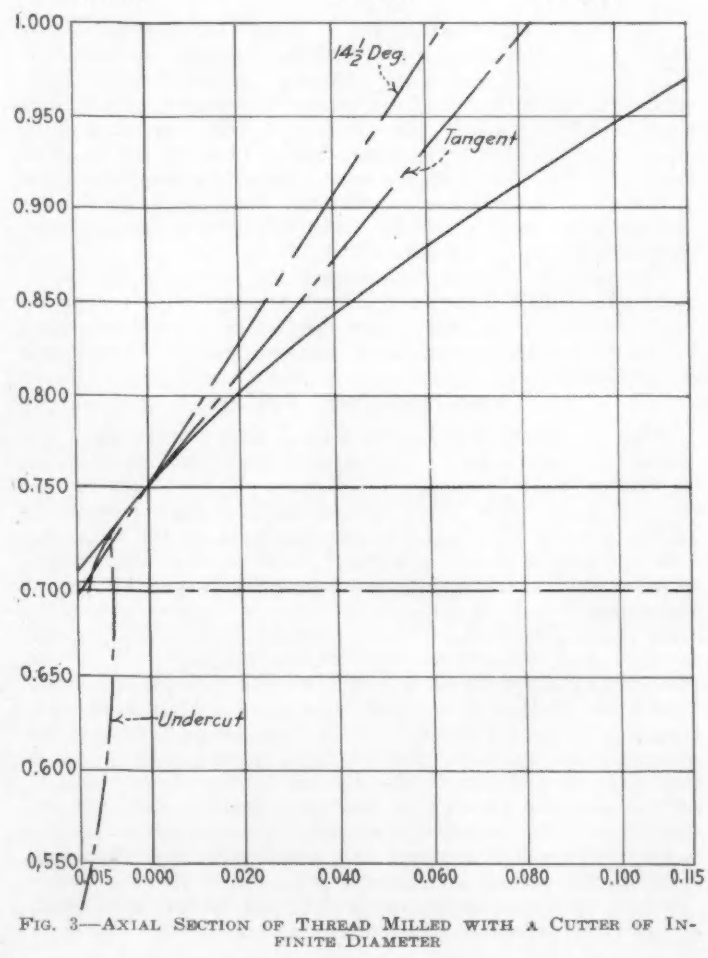

FIG. 3—AXIAL SECTION OF THREAD MILLED WITH A CUTTER OF INFINITE DIAMETER

Solving the equation for the tangent at the pitch radius of 0.75 in. we get

$$\tan \phi = 2.94787$$
$$\phi = 71 \text{ deg. } 15 \text{ min. } 40 \text{ sec.}$$

This profile and its tangent are plotted in Fig. 3, as before. The actual profile of a milled thread will be somewhere between this plotted profile and that of a chased thread. The larger the diameter of the cutter or grinding-wheel is, the closer the actual profile will be to the one plotted in Fig. 3. The smaller the diameter of the milling-cutter is, the farther the actual profile will depart from the one plotted in Fig. 3 toward the profile of the chased thread plotted in Fig. 2. It will be noted that the tangent to this profile at the pitch-line is greater than the angle of the milling-cutter. In this limiting case, this angle measured from a perpendicular to the axis is equal to 18 deg. 44 min. 20 sec.

Except in extreme cases it is possible to make the cutting edges of the milling-cutter slightly convex so that they will produce a practically straight-line section in the axial plane. The radius of curvature of such a cutter or grinding-wheel may be calculated as follows:

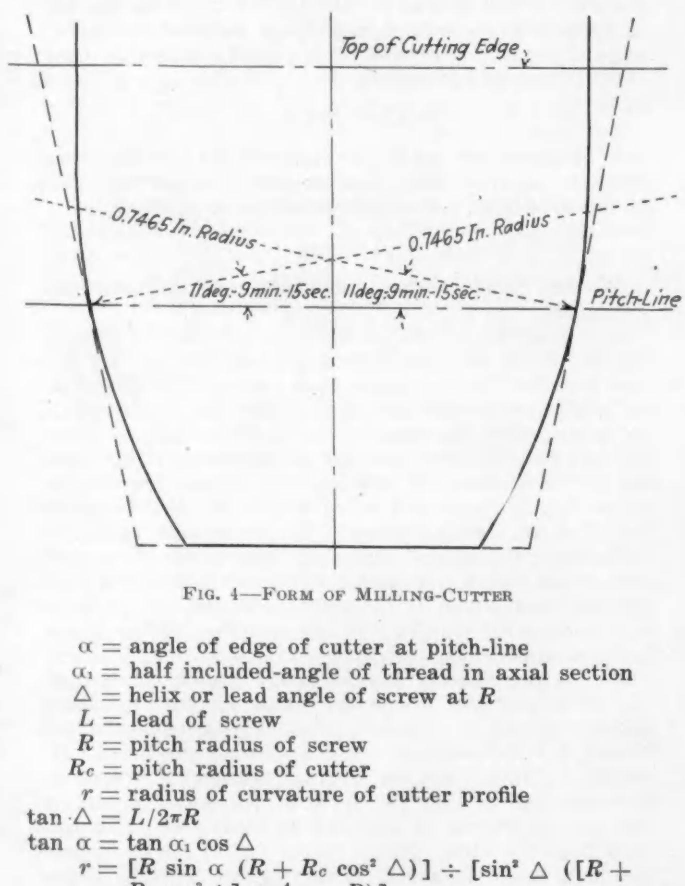

FIG. 4—FORM OF MILLING-CUTTER

α = angle of edge of cutter at pitch-line
α_1 = half included-angle of thread in axial section
Δ = helix or lead angle of screw at R
L = lead of screw
R = pitch radius of screw
R_c = pitch radius of cutter
r = radius of curvature of cutter profile

$$\tan \Delta = L/2\pi R$$
$$\tan \alpha = \tan \alpha_1 \cos \Delta$$
$$r = [R \sin \alpha \ (R + R_c \cos^2 \Delta)] \div [\sin^2 \Delta \ ([R + R_c \cos^2 \Delta] \cos^4 \alpha - R)]$$

As a definite example, the calculation of the radius of curvature for a 3-in.-diameter milling-cutter which is to mill the same Acme thread as before gives the following values:

$$\alpha_1 = 14 \text{ deg. } 30 \text{ min.}$$
$$R = 0.75000$$
$$R_c = 1.50000$$
$$L = 4.00000$$
$$\tan \Delta = 0.84882$$
$$\Delta = 40 \text{ deg. } 19 \text{ min. } 30 \text{ sec.}$$
$$\tan \alpha = 0.25862 \times 0.76239 = 0.19717$$
$$\alpha = 11 \text{ deg. } 9 \text{ min. } 15 \text{ sec.}$$
$$(R + R_c \cos^2 \Delta) = (0.75000 + 1.50000 \times 0.58124) = 1.62186$$
$$r = [0.75000 \times 0.19345 \times 1.62186] \div [0.41876\ (1.62186 \times 0.92655 - 0.75000)] = 0.7465$$

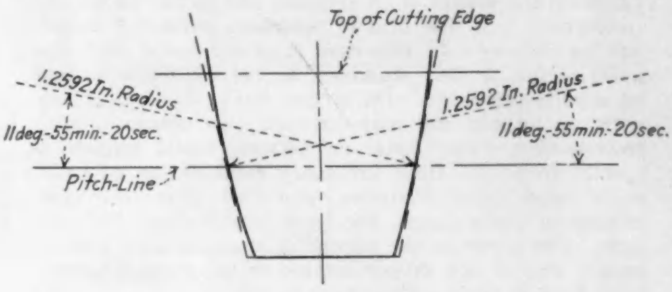

FIG. 5—ANOTHER FORM OF MILLING-CUTTER

This cutter profile is shown in Fig. 4. In this case the cutter would have parallel sides above the radius. The conditions here are so extreme that a satisfactory thread form could hardly be milled. Some improvement would be possible with a small cutter, but too small a cutter would lead into other practical difficulties. This adds further emphasis to the point that the coarseness of the pitch should be limited by the diameter. In this case a thread with 8 starts of ½-in. pitch would be the extreme for this diameter of 2 in. According to the suggested series, this thread should be 0.4-in. pitch with 10 starts. Such a thread could be milled to advantage and would have the following values:

$$\alpha_1 = 14 \text{ deg. } 30 \text{ min.}$$
$$R = 0.90000$$
$$R_c = 1.50000$$
$$L = 4.00000$$
$$\tan \Delta = 0.70736$$
$$\Delta = 35 \text{ deg. } 16 \text{ min. } 30 \text{ sec.}$$
$$\tan \alpha = 0.25862 \times 0.81639 = 0.21113$$
$$\alpha = 11 \text{ deg. } 55 \text{ min. } 20 \text{ sec.}$$
$$(R + R_c \cos^2 \Delta) = 0.90000 + 1.50000 \times 0.66649 = 1.89974$$
$$r = [0.90000 \times 0.20658 \times 1.89974] \div [0.33351\ (1.89974 \times 0.91647 - 0.90000)] = 1.2592$$

This cutter profile is plotted in Fig. 5. It will be noted that, with a given angle of straight-sided tool, the tangent to the profile of the screw-thread in the axial section is less than the angle of the chasing-tool and is greater than the angle of a milling-cutter. This eliminates the possibility of specifying a standard form of cutting edge for all tools and maintaining a constant standard for the product. It therefore seems most logical to specify the form of the axial section of the product for Acme threads, as has been done with all other thread-forms, and to modify the form of the cutting edges on the tools when necessary to produce this form within the specified limits. The pitch must of necessity be specified for this axial section, and the thread form there should logically be constant also.

To ascertain manufacturing practice relative to the thread section of Acme threads on which the 29-deg. profile is considered standard, a questionnaire was addressed to several manufacturers last October, the answers to which are as follows:

Question 1

In your Acme thread work, is the profile on any section other than the axial section considered standard?

Answers

The axial section of the Acme thread is considered standard.—Company *A*.

In general, the tooth profile on the axial section only has been considered standard.—Company *B*.

We use the standard 29-deg. Acme thread and the profile of the axial section is considered standard.—Company *C*.

In the matter of the form of Acme threads our procedure varies with the nature of the work to be done. On small work, done with taps and dies, we rely en-

tirely on the maker of those tools, and so far as we are concerned, it is for him to maintain whatever standard he chooses. In this case it is our belief that the axial section is held standard, as the tools are formed on a relieving lathe. On larger work, it is customary with us to mill the male thread. To obtain a true rack-section, either axial or normal, would require a special form of cutter for every combination of lead-angle and pitch-diameter and we therefore use neither of these forms, but have standardized the cutters. The error in the thread is slight and of such a nature that it can be conjugated in the female thread with formed tools.—Company *D*.

We always consider the profile of the thread in an axial plane.—Company *E*.

We consider the axial section as standard.—Company *F*.

In our Acme thread work we do not consider the axial section as standard.—Company *G*.

We always use the normal profile.—Company *H*.

Question 2

If the axial section is considered as standard, what is the maximum helix-angle to which it can be applied? Also, do you modify the form of the cutting-tool profile to assure correct thread-profile?

Answers

The maximum helix-angle to which we have applied it is 5 deg. 52 min. or 1-1/8-diameter 3-pitch Acme thread. We modify the cutting tool to assure correct thread-profile.—Company *A*.

It would be difficult to state what would be the maximum helix-angle for a straight-sided axial section for Acme threads. For our own work, Acme threads being used for feed screws and table feed screws, the helix-angle does not exceed 15 deg. However, we see no reason why it could not be greater.

The primary considerations are the method and difficulties of manufacture of the tap for the nut, and also the screw. The majority of screw-threads, Acme threads or worm threads, are finished in the thread-milling machine with a rotary cutter which may have straight sides or a formed-shape profile. So far as the efficiency of the cutter is concerned the shape is immaterial except for screws of very large helix-angle when the sides of the formed cutter near the point become nearly parallel and there is little or no cutting clearance on the cutter.

It is this limitation primarily that governs the maximum helix-angle if the tooth profile is straight-sided on the axial section and the included angle of thread is maintained.

It is always necessary to modify the shape of the cutting tool if made for a section other than that of the original profile. Transfer from the axial profile, if straight-sided, to the normal profile can usually be made by calculating the new angle, using the tangents of the normal and axial pressure-angles and the cosine of the thread-helix angle, up to a thread angle of 12 to 15 deg. This procedure may be followed whether the thread is to be finished by a normal chasing-tool or a cutter. For angles over 15 deg. it is generally necessary to fit the normal chasing-tool to a profile obtained from a master or sample worm which has been produced with an axial tool. The axial tool, having extreme clearances, would be unsuitable for manufacture but is used merely to produce the sample when the chasing-tool which cuts on the normal is made to fit the normal section of the sample. In the case of a cutter, the cutter must be "wiped" out to this same sample, or the shape might be developed as outlined in the Buckingham treatise, although for the average shop the method we suggest is simpler in that it is a straightforward mechanical operation. The other is a mathematical one and if only used once in a great while would probably not be so easy or understood as well as the one we have just outlined.—Company *B*.

We have never determined the maximum helix-angle to which the axial section can be applied. The largest helix-angle that we have applied to our standard Acme threads is approximately 9 deg. We modify the form of the cutting-tool shape to assure correct thread-profile when we cut Acme threads that are not standard and have large helix-angles. We use standard Acme gages and fit the screw to the gage by red-leading the screw and correcting the profile until we get the screw to fit the gage.—Company *C*.

We cannot give you the maximum helical angle because we always use a single-pointed tool with coarse Acme threads.—Company *E*.

We cannot give definite information as we have had no need to go into this matter very deeply but would say that if the helix-angle is perhaps 6 or 8 deg. with the end of the screw, we would correct the cutting tool so as to give straight sides on the linear section.—Company *F*.

We do not modify the form of the cutting tools to assure correct thread-profile except that we do find it necessary on large-pitch Acme threads to modify somewhat the tooth-form of the racks in which those threads engage.—Company *G*.

Question 3

If the standard profile is specified for sections other than the axial section, what is your practice and what is the minimum helix-angle to which it applies?

Answers

We invariably work to the customers' specifications. —Company *A*.

Our practice is similar to that outlined in answer to question 2 in regard to modifying the cutting tool and transferring the shape from one method or section to another. We do not appreciate that there would be any conditions that would govern the minimum helix-angle. If the specified tooth-profile is on some section other than the axial, screws with a small helix-angle can be developed as readily as if it were specified for the axial section. To appreciate fully the difficulties of cutting high helix-angles of the standard 29-deg. profile, samples should be made and then consideration given to the screw, the tools for making it, the taps for making the nut and the quality of the tools, if made.—Company *B*.

We do not specify any standard profile other than the axial section. However, when we cut worms of helix-angles of 15 deg. or more, the dimensions of the thread are measured at right angles to the helix. Of course in this case the normal section is standard. It seems logical that the form of the axial section of the product should be specified as standard. This has been done for other thread-forms and it allows, where the helix-angle is great, modifying the cutting edges of the tool to produce the correct profile.—Company *C*.

For cutters or tools to cut a standard profile for any section other than the axial section, we would generate properly shaped cutting tools to give the section required. This would apply to practically all helix-angles as low as perhaps 2 or 3 deg.—Company *F*.

We consider the section normal to the helix-angle as the standard, as it facilitates gaging and simplifies the cutter equipment, practically all Acme threads being made on the thread-milling machine.—Company *G*.

We use the normal profile because we cut all our screws by means of milling-cutters or lathe tools of an included angle of 29 deg., and such cutters or tools are inclined to the proper helix-angle. No minimum helix-angle is fixed at present.—Company *H*.

FOUNDRY FLASK STANDARDIZATION

Recommended Practice Part of the Economic Program for Foundry Equipment

The Joint Committee on Pattern Equipment Standardization that is sponsored by the American Foundrymen's Association and on which the American Society for Testing Materials, the National Association of Purchasing Agents, the Electric Steel Founders Research Group, the Foundry Equipment Manufacturers Association, the American Malleable Castings Association, the National Association of Pattern Manufacturers, and the Steel Founders Society of America are cooperating, has issued the following recommended practice for foundry flask standardization. The Committee, of which D. M. Avey of Cleveland is general chairman, is desirous of receiving the ideas and suggestions of practical foundry operators. Any comments bearing on this report directed to the Society's Standards Department will be forwarded to Mr. Avey. The report, as circularized by the Joint Committee referred to above, follows:

Report of Joint Committee on Pattern Equipment Standardization

Marking Gaged Surfaces and Locating Points on Patterns.—When surfaces of castings are to be accurately gaged though not machined, the gaged surfaces or points should be indicated by distinctive markings such as by painting a special color or inserting a metal disc, care being taken that the marking does not interfere with the pattern draw.

Locating-points for machining operations should be indicated on the pattern by distinctive markings such as a color or metal disc insert, providing that the marking will not interfere with the pattern draw.

Both gaged surfaces and machining locating-points of castings should be shown on the blueprints and, wherever practical, locating-points shall not appear on cored surfaces.

Markings Indicating Chilled Surfaces and Metal Inserts on Patterns.—When internal chills or metal inserts are necessary "chill" or "metal insert" should be stamped on the place to be chilled or on the prints of the metal insert.

Color Ingredients of Coating Materials for Marking Patterns.—When patterns are to be painted according to the Committee's approved standard color-scheme, the paints or shellacs to secure the standard color markings may be obtained by a medium vermillion red powder with white shellac for the red color and a pale yellow ochre mixed with ordinary yellow or white shellac for the yellow color.

Pattern Letters.—Pattern letters best suited for steel and brass castings are the round-faced or flat-faced gothic pattern letters; pattern letters best suited for gray iron and aluminum castings are the sharp-faced or hairline pattern letters.

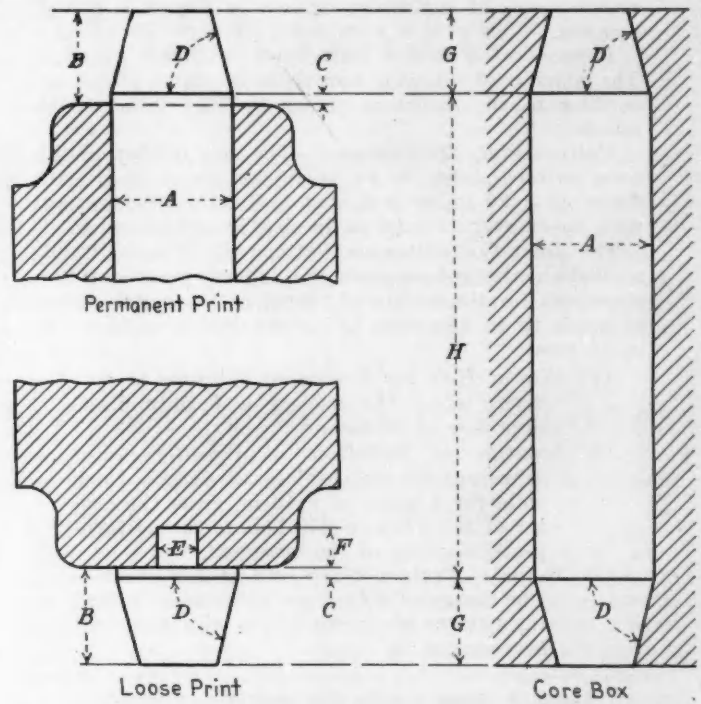

FIG. 1—PROPOSED STANDARDS OF CORE PRINTS FOR METAL PATTERNS
The Dimensions for Various Sizes of Core Print Are Given in Table 2 on p. 12

Loose Pieces for Patterns and Core Boxes.—All loose pieces for patterns and cores, and the prints for the loose pieces on the patterns and core boxes, should be marked consecutively so that a No. 1 loose piece will fit a No. 1 print, a No. 2 loose piece will fit a No. 2 print and so on. When right and left loose pieces are called for, the print should be stamped R or L and the letters R and L stamped on the respective loose pieces. As a factor of safety it is recommended that the pattern-maker use one small and one large dowel-pin to eliminate the danger of loose pieces being reversed.

Leather Fillets.—The use of fillet sizes as given in Table 1 is recommended.

Core Prints for Metal Patterns.—In determining the size and shape of core prints for metal patterns, the design and sizes shown in Fig. 1 are recommended.

Lug Design for Match-Plates.—The use of lugs on

TABLE 1—SIZES OF LEATHER FILLETS

Thickness of Wall, In.	Material of Casting	Thickness of Wall, In. Up to ⅛	⅛ to ¼	¼ to ⅜	⅜ to ½	½ to ⅝	⅝ to ¾	¾ to ⅞	⅞ to 1
Up to ⅛	Iron and Steel	¼		⅜	⅜	⅜	½	½	⅝
	Malleable Iron	⅛		¼	¼	⅜	⅜	½	½
	Copper and Alloys	¼		⅜	⅜	⅜	½	½	⅝
⅛ to ¼	Iron and Steel	⅜	⅜		⅜	½	½	⅝	⅝
	Malleable Iron	⅛	¼		⅜	⅜	½	½	⅝
	Copper and Alloys	⅜	⅜		⅜	½	½	⅝	⅝
¼ to ⅜	Iron and Steel	⅜	⅜	⅜		½	⅝	⅝	¾
	Malleable Iron	¼	¼	⅜		½	½	⅝	⅝
	Copper and Alloys	⅜	⅜	⅜		½	⅝	⅝	⅝
⅜ to ½	Iron and Steel	⅜	⅜	½	½		⅝	¾	¾
	Malleable Iron	¼	⅜	⅜	½		⅝	⅝	¾
	Copper and Alloys	⅜	⅜	½	½		⅝	⅝	⅝
½ to ⅝	All Metals	⅜	½	½	⅝	⅝		¾	¾
⅝ to ¾	All Metals	½	½	⅝	⅝	¾	¾		¾
¾ to ⅞	All Metals	½	⅝	⅝	¾	¾	¾	1	
⅞ to 1	All Metals	⅝	⅝	¾	¾	¾	1	1	1

match-plates of the design shown in Fig. 2 is recommended.

Position of Vibrator Bolt-Holes in Match-Plates.—The placing of vibrator bolt-holes in match-plates according to the positions shown in Fig. 2 is recommended.

Pattern-Plate Thicknesses.—The use of flat aluminum pattern-plates 3/8 in. thick for plates used with flasks 12 x 20 in. or less, and 1/2 in. thick when used with flasks over 12 x 20 in. in size, is recommended.

The Joint Committee on Pattern Equipment Standardization also recommends the following as tentative standards for the design of vibrators for match-plates as applying to vibrators up to and including those 3/4 in. in size.

(1) *Size of Hole for Fastening Vibrator to Pattern-Plate.*—The use of a 5/16-in.-diameter hole in vibrators

(2) *Location of Bolt-Hole in Vibrators.*—For vibrators for match-plates, a design which calls for a space of 9/16 in. from the center of the vibrator bolt-hole to the pattern-plate shoulder of the vibrator

(3) *Shape of Pattern-Plate End of Vibrators.*—The design of vibrators which specify that the pattern-plate end of the vibrator shall be rounded

TABLE 2—CORE PRINTS FOR METAL PATTERNS[1]

A	*B*	*C*	*D*	*E*	*F*	*G*	*H*
3/16	17/64	1/32	88°	1/8	3/16	15/64	1 1/2
7/32	19/64	1/32	88°	1/8	3/16	17/64	1 1/2
1/4	21/64	1/32	85°	1/8	3/16	19/64	1 3/4
9/32	23/64	1/32	85°	1/8	3/16	21/64	1 3/4
5/16	25/64	1/32	85°	3/16	3/16	23/64	2
11/32	27/64	1/32	85°	3/16	3/16	25/64	2
3/8	15/32	3/64	85°	3/16	3/16	27/64	2 1/2
13/32	1/2	3/64	81°	3/16	3/16	29/64	2 1/2
7/16	17/32	3/64	81°	1/4	1/4	31/64	2 3/4
15/32	17/32	3/64	81°	1/4	1/4	31/64	2 3/4
1/2	17/32	3/64	81°	1/4	1/4	31/64	3
17/32	9/16	3/64	81°	1/4	1/4	33/64	3
9/16	9/16	3/64	81°	1/4	1/4	33/64	3
19/32	37/64	3/64	76°	3/8	1/4	17/32	4
5/8	19/32	1/16	76°	3/8	1/4	17/32	4
21/32	5/8	1/16	76°	3/8	3/8	9/16	4
11/16	5/8	1/16	76°	3/8	3/8	9/16	4
23/32	21/32	1/16	76°	3/8	3/8	19/32	4
3/4	21/32	1/16	76°	3/8	3/8	19/32	4
13/16	23/32	1/16	76°	3/8	3/8	21/32	5
7/8	25/32	1/16	76°	3/8	3/8	23/32	5
15/16	25/32	1/16	76°	3/8	3/8	23/32	5
1	55/64	5/64	76°	3/8	3/8	25/32	5
1 to 1 1/4	59/64	5/64	76°	1/2	1/2	27/32	6
1 1/4 to 1 1/2	1 1/16	3/32	76°	1/2	1/2	31/32	6
1 1/2 to 1 3/4	1 5/32	3/32	76°	1/2	1/2	1 1/16	6
1 3/4 to 2	1 19/64	7/64	76°	1/2	1/2	1 3/16	6
2 to 2 1/2	1 7/16	1/8	76°	3/4	5/8	1 5/16	8
2 1/2 to 3	1 9/16	1/8	76°	3/4	5/8	1 7/16	8
3 to 4	1 13/16	1/8	76°	1	3/4	1 11/16	10

Note.—It is essential that the cope and drag prints be identical and that the dimension *H* in both core box and print correspond. When dimension *H* is increased, *G* should also be increased proportionately. Note the difference in the over-all length of the core box and prints.

[1] The drawing accompanying this table is printed on p. 11.

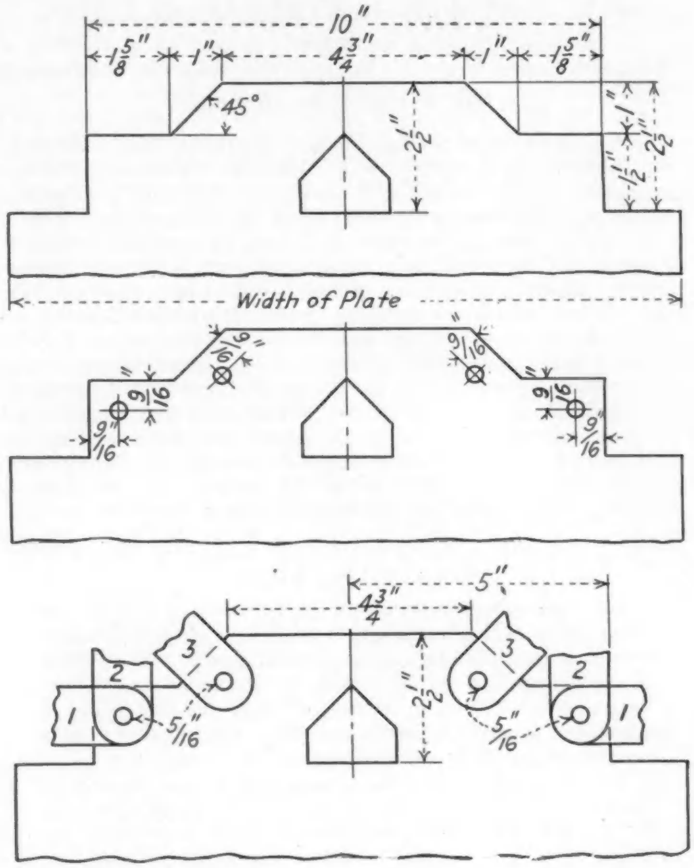

FIG. 2—DRAWING SHOWING (TOP) PROPOSED LUG DESIGN FOR AND (CENTER) LOCATION OF VIBRATOR BOLT-HOLES IN MATCH-PLATES AND (BOTTOM) POSSIBLE POSITIONS OF VIBRATORS ON STANDARD LUGS

MACHINE TAPERS TO BE STANDARD

Wide Variation in Machine-Tool Practice Indicated by Preliminary Survey

One of the major features of construction in machine-tools and related equipment that causes about as much trouble as anything else for machine-tool users is the lack of uniformity in the dimensions and tapers of tapered mating-parts such as drill spindles and sockets. With the increased interest in standardization in the machine-tool industry within the last few years, a desire for adequate standardization of tapers has been indicated from a number of sources. The machine-tool users desire particularly that this work should go forward as rapidly as possible because, under existing conditions, the tapers of parts and tools commonly used vary among different makes of such elements enough to prevent interchangeability but not enough to militate against standardization for interchangeability. Consequently, since the organization of the Sectional Committee on Small Tools and Machine-Tool Elements, by the Society, the American Society of Mechanical Engineers and the National Machine Tool Builders Association, a conference was held, about a year ago, at which it was decided to organize a Subcommittee to study and report on the standardization of machine tapers.

A tentative preliminary report was drafted that included series of tapers based on the present Morse, Brown & Sharpe, and Jarno series, but modified to some extent. Before issuing this report the Subcommittee reviewed it at a meeting held at White Sulphur Springs, W. Va., on May 24 of this year, at which time it was decided that before circular-

(*Concluded on p. 20*)

Operation and Maintenance

ECONOMICAL LIFE OF MOTOR-VEHICLES

Ohio State University Students Conduct Series of Tests on Fleet of Taxicabs

U. J. Grant, P. A. Harlamert, W. A. Meiter, and R. S. Osborn, four senior students at Ohio State University, have been collecting data from tests on taxicabs to show the value of such tests. They are preparing a thesis entitled The Economical Life of Commercial Passenger-Vehicles. The tests were made under the supervision of Prof. H. M. Jacklin on 14 taxicabs, using a chassis-testing dynamometer and other equipment. Taxicabs only were tested, inasmuch as they could be selected from one organization, thus obviating variations due to different service methods and policies. The cabs were grouped into five principal classes according to various lengths of service. Thus, three cabs which had traveled 40,000 miles were tested to obtain an average in this class. Other groups of three were for 75,000, 110,000 and 140,000 miles. Two other cabs which had been driven 30,000 miles in Pittsburgh, then reconditioned at the factory and driven 20,000 miles in Columbus were tested. One of the cabs which was driven 140,000 miles has been reconditioned since the test was made. It will be tested again after several weeks of service to see what improvements have resulted.

The chassis-testing dynamometer is equipped with a traction scale so that direct readings may be taken on each vehicle. Each vehicle was weighed and its frontal area determined. The "road-load" for average driving conditions was then calculated for four speeds, 15, 20, 25, and 30 m.p.h. Fuel-consumption tests were then made at each of these speeds with the throttle set to carry the corresponding load.

The dynamometer and traction scale were used to determine the friction loss in various parts of the vehicle; so it was possible to obtain values for engine horsepower, efficiency of transmission and fuel consumption. A gasometer of about 2-cu. ft. capacity was arranged to collect the gases and vapors ordinarily lost through the crankcase breather. This gasometer gives a measure of the leakage past the pistons. Samples of oil were taken from the crankcase before and after making tests to find the increase in oil dilution. A pressure-gage fitted with a small check-valve was arranged to obtain the compression pressure of the various cylinders.

Short runs were made to determine the power available with the throttle held wide-open, so that the available acceleration might be calculated. No fuel-consumption data were collected for these runs because of the rapid overheating of the engines even when a rather strong blower was used in front of the radiator.

Aside from the tests outlined above, observations were made on (*a*) front-wheel alignment, (*b*) pedal adjustments, (*c*) ease of shifting gears, (*d*) braking, (*e*) spring-shackles, where used, and (*f*) condition of wheels.

To date, the results indicate that the over-all efficiency of these vehicles is rather good up to between 100,000 and 120,000 miles, with a rather abrupt change after attaining this mileage. Cabs driven up to 110,000 miles showed figures for over-all efficiency ranging from 10 to 12 per cent, while three cabs which had been driven 140,000 miles showed but 7 to 8 per cent. Only one of the latter three cabs would pull a load corresponding to 30 m.p.h. The horsepower required to overcome the friction of the vehicle was from 50 to 100 per cent higher in these than in the younger cabs, while the maximum horsepower that the engines would deliver had decreased greatly, more particularly at 25 and 30 m.p.h. The older the cab the greater the difficulty in having the engine pull well at wide-open throttle, due to very serious "spiking" even when there was a very small carbon-deposit. It is thought that this trouble may be caused by heavy scale deposits in the water-jackets.

Although the complete report on these tests is not yet available, it appears that such tests will be valuable in judging the condition of the vehicle, as showing wherein the used vehicle can be improved, generally at very small expense compared to trading-in for a new one; and in checking the work of the service department in reconditioning the vehicle.

NEW JERSEY MOTORCOACH REGULATIONS

New Jersey Board of Public Utility Commissioners Issues Final Specifications

The revision of the motorcoach regulations that were adopted by the Board of Public Utility Commissioners in New Jersey in 1924 was completed by the adoption by the Board of a new set of regulations on April 28. The Motorcoach Division of the Society's Standards Committee has devoted considerable time to the study of these regulations and has cooperated with the New Jersey officials toward making the revised regulations as practical and valuable as possible to the regulatory officials, the motorcoach manufacturers and the operators and toward assuring the comfort and safety of the traveling public. The activity of the Division in this connection was referred to in the January, March and April issues of THE JOURNAL.

An important change from the old regulations is the dividing of motorcoaches into two classes, (*a*) the city-type single-deck vehicles and (*b*) the parlor-car type. Regulations that apply to one and not the other are indicated in the new code, whereas under the old code some confusion resulted because no such distinction was definitely indicated. The body dimensions were determined largely by local operating conditions in more congested centers, bearing in mind the comfort of passengers, particularly where standees are permitted.

One of the most important revisions in the old regulations is the provision that the emergency door may be located in the center rear or elsewhere as the Board may direct. This item was one that gave the motorcoach manufacturers much concern and it is felt that the New Jersey Board has done much to relieve the manufacturers of a rather severe hardship.

Another major change that it is felt has greatly improved the new specifications is the modification of the item for chassis frames from a dimensional specification to that given below. The purpose of the old dimensional specification was to enable the motor-vehicle administrators to guard against the operation of motor-truck chassis converted into motorcoaches or buses, but it is generally recognized now that the day of this type of converted vehicle has passed and that careful engineering design is used in the framing for all motorcoaches that are going into operation.

Another advanced provision of the regulations is that the exhaust-pipe shall be extended to the rear end of the vehicle or to the front of the left rear-wheel. This is in line with the experienee of the motorcoach operators in overcoming the suction of obnoxious gases into the motorcoach body, by carrying them into the agitated air in and around the wheel housing, thus diluting the exhaust gases and diverting them from the air-swirl at the rear of the vehicle.

The principal clauses, with their official numbers, of the new regulations are as follows:

> Auto buses shall be divided into two classes, known as *A* and *B*.
>
> *A—City-Type, Single-Deck.*—The city-type, single-deck bus includes all buses engaged in the transportation

of passengers, so designed that the carrying capacity is not limited to the seated load, standing passengers being allowed to be carried.

B—Parlor-Car Type.—The parlor-car type includes all buses engaged in the transportation of passengers where the carrying capacity is limited to the seated load. This type of motorbus is not intended to carry standees.

It is proposed that the following specifications shall apply to buses of both types except where distinctions are noted:

(1) The maximum length of body shall be such that the maximum length of vehicle shall not exceed 28 ft. The minimum length of the body shall be 16 ft. The maximum and minimum widths of body shall be 8 and 7 ft. outside measurements respectively. The maximum inside-height shall be 6 ft. 9 in. and the minimum inside-height 6 ft. 4 in., in the center, except that the minimum inside-height for Class-*B* buses shall be 5 ft. in the center.

(4) A partition of wood and glass shall be located behind the driver's seat in Class-*A* buses and so designed as to permit proper ventilation at the top. In Class-*B* buses a suitable curtain shall be provided so arranged as to shield the driver from the glare of inside lights.

(6) An emergency door located at the center-rear or elsewhere, as the Board may direct, shall be provided. This door shall have the minimum clearance of 18 in. and extend from the floor to the upper belt-panel.

(*a*) The emergency door shall be conspicuously marked "Emergency Door."

(*b*) Provision shall be made whereby the emergency door may be readily opened by passengers in case of emergency.

(*c*) The rear of the auto bus shall be constructed so that no permanent obstruction will interfere with the passage of passengers through the emergency door.

(*d*) The rear frame of the auto bus shall be so designed and constructed as to minimize so far as possible rendering the emergency door inoperative in case of accident.

(7) The construction of the front end of auto-bus bodies shall be such as to afford the driver an unobstructed vision to the right and the left. A small opening must be placed on the left-hand side of the driver to provide for signaling.

(12) The gasoline tank shall not be located inside the body of the bus. Tanks shall be filled and drained from the outside.

(15) An interior lighting installation shall be provided which shall be at least 5 rated cp. per seat-passenger capacity, lamps to be so located as to provide an even distribution of light. A step-light shall also be provided.

Lighting installation, including generator, shall be so designed that the lamps shall burn at normal brilliancy.

(18) A sign shall be provided and so located that it may be read day or night from at least 100 ft. ahead of the vehicle, indicating on Class-*A* buses the route, and on Class-*B* buses the destination. This sign must not interfere with the driver's vision or produce an annoying glare.

(19) The maximum overhang of the body shall be in proportion of 7/24 of the total length of the vehicle; vehicle measurements to be taken from front of radiator to rear end of body. Overhang measurements to be taken from rear axle to rear end of body.

(20) The chassis frame shall be so designed and constructed that it will properly and safely carry the body which it supports, together with its full-capacity passenger-load.

(21) The maximum height of frame from the ground to the top of the chassis frame shall be 32 in. in Class-*A*, and 30 in. in Class-*B* buses when measured without passenger load at the service door.

(22) The body shall not extend more than 15 in. beyond the chassis frame at the rear.

(24) Not less than two sets of brakes, each operating independently of the other, shall be provided, except that with four-wheel mechanical brakes two separate controls alone will suffice.

(25) Solid rubber tires will not be allowed. This is not intended to exclude the use of cushion tires.

(26) Wheel housings shall be so designed and constructed as to provide proper protection to occupants of the bus in case of tire trouble. The design of the mudguard shall be such that no undue accumulation of dirt or foreign matter can be deposited on the body.

(27) The exhaust-pipe, including exhaust-heater pipes, shall be extended to the rear end or to a point immediately in front of the left rear-wheel.

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Automotive Research

STARTING-ABILITY OF FUELS COMPARED

Cracked Versus Straight-Run Gasolines Investigated in Cooperative Research

Decided interest attaches both to the material and the methods treated in the following paper, prepared by D. C. Ritchie,[1] in the course of the Cooperative Fuel-Research being carried out at the Bureau of Standards under the sponsorship of the National Automobile Chamber of Commerce, the American Petroleum Institute and this Society. The paper, presented by H. K. Cummings,[2] was one of the many attractive features of the Research Session of the Semi-Annual Meeting.

The proportion of the total of this Country's supply of gasoline produced by cracking processes increased from 6 per cent in 1920 to 31 per cent in 1926, and, in the opinion of oil technologists, this type of fuel will continue to bulk larger and larger in importance. Mr. Ritchie's paper covers one of the important characteristics of cracked gasoline, and compares it, in this respect, with straight-run gasolines and other motor fuels.

The results arrived at in this investigation are contrary to those which might have been expected in view of certain previous tests carried out by other experimenters which seemed to indicate that a difference would be observed in the case of starting as between straight-run and cracked gasolines of similar volatility characteristics. In discussing the paper, Mr. Cummings said that the earlier work where such a difference was suggested appeared to have been subject to difficulties that were present in the Bureau's early bomb experiments, namely, the influence of surface effects.

Besides describing this improvement in the method for determining the lean explosive limits of fuel, the paper introduces another interesting question relating to methods, the effect of velocity of flow of the fuel-air mixture and of the length of the spark gap and spark intensity on the lean explosive limits.

The investigation described in this paper was made as a result of a definite inquiry on the point covered, all the work on the subject of starting included in the program of the Cooperative Fuel Research having been completed. Further investigation into factors affecting engine starting will be carried out only to meet any specific inquiry raised that is thought to involve a point of general interest.

Mr. Ritchie's paper follows.

Lean Explosive-Limits for Cracked and Straight-Run Gasolines and Other Motor Fuels[3]

Information regarding the relative ease of engine starting with cracked and straight-run gasoline was requested at the 1926 annual meeting of the American Petroleum Institute following the presentation of a report on Fuel Characteristics and Engine Starting[4] by J. O. Eisinger and T. S. Sligh, Jr.

Since the Bureau of Standards had made no tests on cracked gasolines in its investigation of engine starting, arrangements were made to supply the Bureau with samples of this type of gasoline from several different sources. Since the volatility of gasoline is the important factor in engine starting, as was brought out in an article entitled Fuel Requirements for Engine Starting, by C. S. Cragoe and J. O. Eisinger,[5] the desired information appeared to be whether cracked and straight-run gasolines of equal volatility would give different starting results. It was decided that this information could best be obtained by determining the lean explosive-limits for fuels of these two types.

SATURATED-VAPOR METHOD

Some of the earliest laboratory measurements of starting characteristics of motor fuels at the Bureau of Standards, described in an article entitled Progress in the Measurement of Fuel Volatility, by T. S. Sligh, Jr.[6] employed a 500-cc. glass flask or "bomb" which was provided with a small fan, a spark gap and a specially constructed stopper. Measured quantities of liquid fuel were supplied to this bomb by calibrated capillary pipettes and the minimum quantity of liquid fuel required to produce an explosive mixture of air and fuel vapor at various temperatures was determined. Measurements made with benzol, petroleum ether and aviation fuels at sufficiently high temperatures for complete evaporation indicated an approximate lean explosive-limit of 26 air-fuel ratio. Similar measurements were made with numerous motor fuels at lower temperatures to obtain relative data as to starting volatility. With only a portion of the fuel evaporated, it was found almost impossible to obtain reproducible results. Considerably different results were obtained with the same fuel and the same temperature by using various liquids for cleaning the bomb after each explosion. Changes in the width of the spark gap and changes in the voltage applied were found to alter the results. After a careful study of this method it was concluded that the relatively large variations in the results were caused mainly by surface effects. With only a small portion of the supplied liquid fuel in the vapor phase, differences in the amount of fuel vapor adsorbed on the walls or absorbed in the unevaporated liquid remaining on the surfaces introduce large variations in the observed results.

SUPERHEATED-VAPOR METHOD

A more accurate method of measuring fuel volatility, known as the equilibrium air distillation method, was developed subsequently by the late T. S. Sligh, Jr. This method, described by him in an article entitled Volatility Tests for Automobile Fuels,[7] consists essentially in supplying measured amounts of air and liquid fuel to an evaporating coil, maintained at constant temperature, and measuring the rate of collection of unevaporated fuel. From these data and the densities of supplied and unevaporated fuels the ratio of air to fuel vapor by weight can be calculated. A detailed description of the apparatus used has been previously published.

The combination of the equilibrium air distillation apparatus and an explosion bomb offered distinct advantages for determining the lean explosive-limit of fuels. By flowing known mixtures of air and superheated fuel-vapor through an explosion bomb for some time, it was found that the difficulties with surface effects previously encountered with wet mixtures were practically eliminated.

The discharge tube of the equilibrium air distillation apparatus, shown in Fig. 1, was connected to the three-necked Pyrex glass bomb of 200-cc. capacity, shown in Fig. 2. Two of the necks were used as inlet and outlet respectively and in the third neck was inserted a 5-mm. spark-gap connected to a spark coil operating on 6 volts. The glass tube containing the connections to the spark gap was wound with asbestos cord at the neck of the flask to give a moderately tight fit and yet not offer sufficient resistance to cause the flask to burst from the explosion of a charge. Safety precautions were taken to prevent back-flash into the equilibrium

[1] Assistant scientific aid, automotive powerplants section, Bureau of Standards, City of Washington.

[2] Associate physicist, automotive powerplants section, Bureau of Standards, City of Washington.

[3] Published by permission of the Director of the Bureau of Standards.

[4] See *American Petroleum Institute Bulletin*, January, 1927, p. 143.

[5] See The Journal, March, 1927, p. 353.

[6] See The Journal, April, 1926, p. 393.

[7] See The Journal, August, 1926, p. 151.

air distillation apparatus by inserting a fine-mesh copper screen in the inlet neck of the explosion flask. The inlet and outlet tubes were connected to a bypass (See Fig. 2) so that observations could be made under static and dynamic conditions.

The method of procedure was to vary the air-fuel ratio supplied so as to determine the leanest resultant mixture of air and fuel vapor which would produce an explosion in the bomb. With the fuel supplied at a definite rate, the rate of air-flow was adjusted to obtain the desired air-fuel ratio. The fixed air-fuel mixture was then allowed to flow through the bomb for several minutes and a spark applied. The duration of the spark was always of the order of 2/5 sec. With a rich mixture, the flame was decidedly yellow and propagated slowly. As the air in the mixture was increased the flame lost its yellow cast, became blue and the

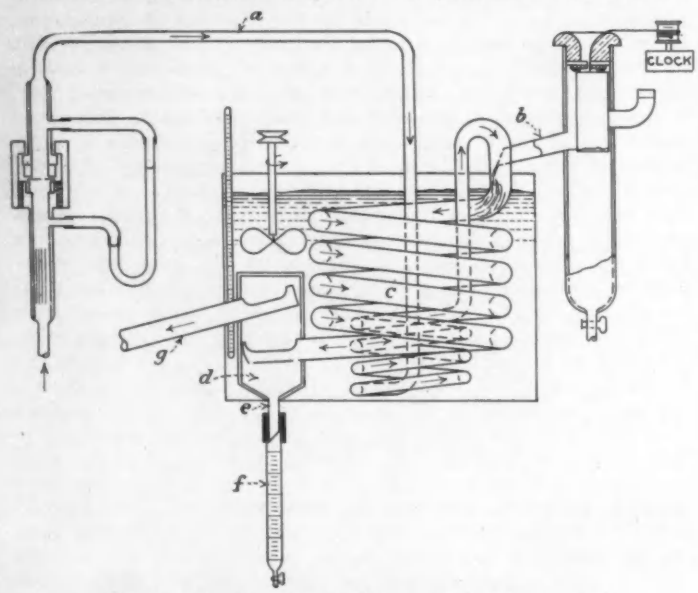


FIG. 1—EQUILIBRIUM AIR DISTILLATION APPARATUS

A Combination of This Device with the Explosion Bomb Shown in Fig. 2 Was Used To Determine the Lean Explosive-Limit of Fuels in the Test Work Here Described. Measured Amounts of Air and Fuel, the Former through Inlet *a*, the Latter through the Inlet *b*, Were Supplied to an Evaporating Coil, *c*, Maintained at Constant Temperature. The Lower End of the Evaporating Coil Delivers into a Separating Chamber, *d*, from Which a Short Tube, *e*, Drains the Unevaporated Liquid into a Graduated Tube, *f*, by Which the Rate of Collection of Unevaporated Fuel Is Measured. From the Data on the Amount of Air and Fuel Supplied, and on the Densities of the Supplied and Unevaporated Fuel, the Ratio of Air to Fuel Vapor by Weight Can Be Calculated. The Known Fuel-Air Mixture Is Passed Through the Discharge Tube *g* to the Pyrex Glass Bomb Shown in Fig. 2

explosion more violent. Leaning the mixture still further the explosion became less violent until finally the limiting explosive mixture was reached. (See Table 1). The lean

TABLE 1—DATA OBTAINED WITH PENTANE AT 20 DEG. CENT. (68 DEG. FAHR)

Resultant Air-Fuel Ratio	Remarks
24.0–1	Violent explosion
25.0–1	Explosion less violent
26.0–1	Flame propagation slowing up
26.1–1	Flame propagation just travels throughout the flask
26.2–1	Flame propagation would not travel throughout the flask

explosive-limit was taken as the leanest mixture which would allow the propagation of flame throughout the entire flask. This limiting mixture is not necessarily the leanest mixture which could be made to burn but is the leanest mixture which would explode under the constant condition of tests.

FUELS AND RESULTS

The samples of cracked gasoline were supplied through the courtesy of Dr. Gustav Egloff of the Universal Oil

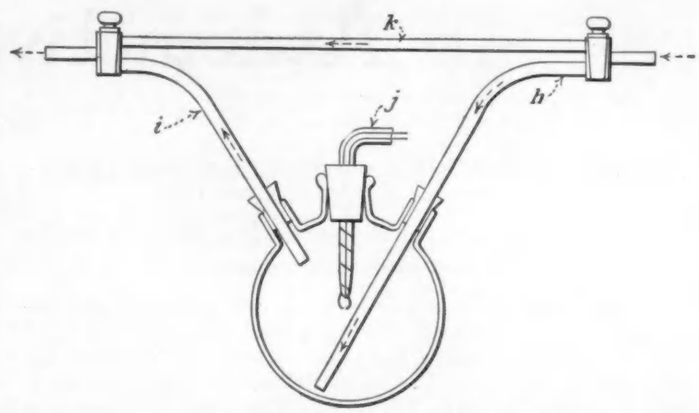


FIG. 2—PYREX GLASS EXPLOSION BOMB

One of the Three Necks, *h*, Is an Inlet, Which Conducts the Known Mixture of Air and Superheated Fuel Vapor from the Discharge Tube of the Equilibrium Air Distillation Apparatus Shown in Fig. 1 into the Bomb. The Second, *i*, Is an Outlet, and in the Third, *j*, Is Inserted a 5-Mm. Spark Gap Connected to a Spark Coil Operating on 6 Volts. The Spark, the Duration of Which Was of the Order of 2/5 Sec., Was Used in Determining the Leanest Resultant Mixture of Air and Fuel Vapor Which Would Produce an Explosion. The Inlet and Outlet Tubes Are Connected to a Bypass, *k*, So That Observations Can Be Made under Static and Dynamic Conditions

Products Co. These fuels were all cracked by the Dubbs process. Fuel *A* came from a Panhandle crude; *B*, California crude; *C*, Smackover heavy fuel-oil; *D*, Wyoming crude; and *E*, Mid-Continent crude. Fuels 1-*A*, 2-*A*, 3-*A*, and 4-*A* were specially prepared and used in the starting investigations of the cooperative fuel-research. Fuel No. 10 is a commercial grade purchased on Federal Specifications for Motor Gasoline. The American Society for Testing Materials distillation curves of the various fuels are shown in Figs. 3 and 4.

The results of the first series of experiments which were made with the mixture flowing through the explosion bomb are given in Table 2. It may be noted that lean limits for cracked and straight-run gasolines were found to be identical within experimental error in the case of the experiments at 20 deg. cent. (68 deg. fahr.), whereas slightly higher limits were found in the experiments at 0 deg. cent. (32 deg. fahr.). The rate of fuel supplied was 2 cc. per min. in all of these experiments. Since the air-fuel ratio

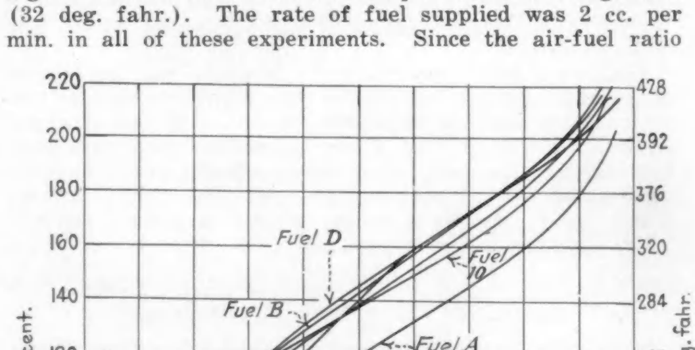


FIG. 3—AMERICAN SOCIETY FOR TESTING MATERIALS DISTILLATION CURVES OF CRACKED FUELS USED IN TESTS

Fuel *A* Came from a Panhandle Crude; *B*, California Crude; *C*, Smackover Heavy Fuel; *D*, Wyoming Crude; and *E*, Mid-Continent Crude

TABLE 2—DATA OBTAINED UNDER DYNAMIC CONDITIONS

Sample	Supplied Air-Fuel Ratio	Per Cent Evaporated by Weight	Resultant Air-Fuel Ratio Lean Limit
Data Obtained at 20 Deg. Cent. (68 Deg. Fahr.)			
Cracked			
A	16.2	69.0	23.4
B	10.5	44.4	23.6
C	12.2	52.7	23.1
D	10.6	45.7	23.2
E	11.9	51.6	23.3
Straight-Run			
1-*A*	12.5	52.2	23.5
2-*A*	11.1	47.7	23.3
3-*A*	10.6	45.1	23.5
4-*A*	10.6	45.3	23.4
Pentane	23.4	100.0	23.4
Petroleum Ether	23.1	100.0	23.1
Benzol	22.8	100.0	22.8
No. 10	12.0	52.2	23.0
Data Obtained at 0 Deg. Cent. (32 Deg. Fahr.)			
Cracked			
A	8.8	35.2	25.0
B	6.5	16.2	24.1
Straight-Run			
1-*A*	5.3	21.7	24.4
3-*A*	3.9	16.9	24.1
Pentane	23.4	100.0	23.4
Petroleum Ether	23.1	100.0	23.1

supplied ranged from 3.9 to 23.4 with the fuel supplied at a constant rate, the air-flow and consequently the rate of flow of the mixture through the bomb varied in these experiments by as much as a factor of 6.

To determine the effect of various velocities of flow through the bomb, without introducing appreciable changes in the vapor composition, three additional experiments were

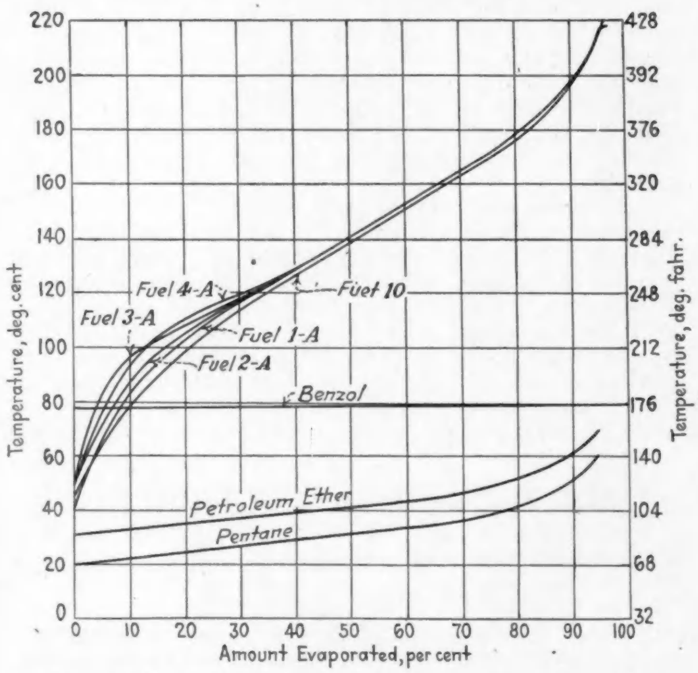


FIG. 4—AMERICAN SOCIETY FOR TESTING MATERIALS DISTILLATION CURVES OF STRAIGHT-RUN GASOLINE AND OTHER FUELS USED IN TESTS

Fuel 1-*A*, 2-*A*, 3-*A*, and 4-*A* Were Specially Prepared and Used in the Starting Investigations of the Cooperative Fuel-Research. Fuel No. 10 Is a Commercial Grade Purchased on Federal Specifications for Motor Gasoline

TABLE 3—DATA OBTAINED UNDER STATIC CONDITIONS AT 20 DEG. CENT. (68 DEG. FAHR.)

Sample	Supplied Air-Fuel Ratio	Per Cent Evaporated by Weight	Resultant Air-Fuel Ratio Lean Limit
Cracked			
A	17.8	70.1	25.3
B	11.9	47.0	25.3
C	13.5	54.0	25.0
D	11.8	47.1	25.0
E	13.2	53.0	24.9
Straight-Run			
1-*A*	14.0	55.9	25.0
2-*A*	12.3	49.1	25.0
3-*A*	11.8	46.5	25.4
4-*A*	12.1	47.8	25.3
Pentane	26.1	100.0	26.1
Petroleum Ether	26.0	100.0	26.0
Benzol	25.7	100.0	25.7
No. 10	13.2	52.7	25.0

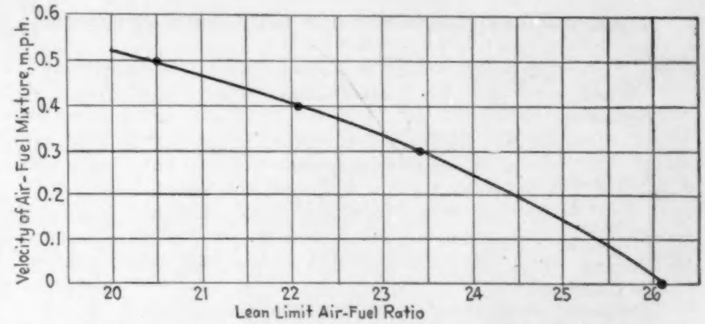


FIG. 5—GRAPH SHOWING EFFECT OF VELOCITY OF FLOW THROUGH THE BOMB ON LEAN LIMIT AIR-FUEL RATIO

The Data on Which the Curve Is Based Were Obtained from Three Experiments Made at 20 Deg. Cent. (68 Deg. Fahr.) on Pentane with No Flow and with Supplied Rate of 3 and 4 Cc. per Min. The Results Obtained Are Plotted against the Air-Flow of the Mixture past the Spark Gap. The Rate of Flow Was Computed from the Volume Rate of Flow and the Cross-Sectional Area of the Bomb

made at 20 deg. cent. (68 deg. fahr.) on pentane, with no flow and with supplied rate of 3 and 4 cc. per min. The results obtained are plotted against the rate of flow of the mixture past the spark gap (See Fig. 5). The rate of flow was computed from the volume rate of flow and the cross-sectional area of the bomb. Several auxiliary experiments were made in which the spark gap ranged from 4 to 7 mm. and the voltage ranged from 4.5 to 7.5 volts. No appreciable effect on the results could be attributed to changes of this magnitude in the spark. The results recorded in Table 2 are not strictly comparable because the rates of flow varied considerably. For this reason a second series of experiments was conducted with no flow through the bomb. The results of this series are given in Table 3. The lean limits for static conditions appear to be between 25 and 26 air-fuel ratio for all the fuels investigated.

COMPARISONS WITH PREVIOUS RESULTS

The lean explosive-limit for a mixture of hydrocarbon vapor and air at atmospheric pressures and temperatures has been found by numerous investigators to depend to a considerable extent upon the size of the explosion vessel and upon the direction of flame propagation, whether downward, upward or horizontal. The results of previous observers, given in Table 4, were obtained for the most part under conditions comparable to those described in this paper. The data were reported in terms of per cent by volume and have

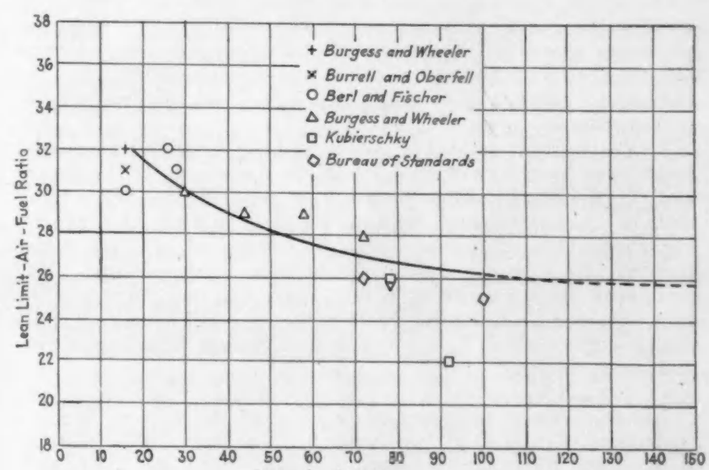


FIG. 6—LEAN EXPLOSIVE-LIMITS OF VARIOUS HYDROCARBONS

In the Graph Are Plotted the Data Set Forth in Table 4, the Results of Previous Observers Which Were Obtained for the Most Part under Conditions Comparable to Those Described in This Paper. The Data Were Reported in Terms of Per Cent by Volume and Have Been Converted to Air-Fuel Ratio for Purpose of Comparison. For the Same Reason Points Representing the Bureau of Standards Findings Have Been Included. The Burgess and Wheeler Results Designated by Crosses Are from Safety in Mines Research Board Paper No. 15; Those Designated by Triangles Are from the Results of the Same Authors as Published in *Journal of the Chemical Society* (Transactions)

TABLE 4—LEAN EXPLOSIVE-LIMIT OF VARIOUS HYDROCARBONS

Fuel	Per Cent by Volume	Air-Fuel Ratio
Methane	5.4	32[a]
	5.5	31[b]
	5.8	29[c]
Acetylene	3.4	32[c]
Ethylene	3.4	29[c]
Ethane	3.1	30[d]
Propane	2.2	29[d]
Butane	1.7	29[d]
Pentane	1.4	28[d]
Benzene	1.4	26[e]
Toluene	1.4	22[e]

[a] See Safety in Mines Research Board Paper No. 15.
[b] Bureau of Mines Technical Paper No. 119.
[c] See *Zeitschrift für Electrochemie*, January, 1924, p. 29.
[d] See *Journal of the Chemical Society*, (Transactions) vol. 99, p. 2013.
[e] See *Zeitschrift für Angewandte Chemie*, February, 1901, p. 129.

been converted here to air-fuel ratio for comparison purposes by assuming the gas law, $PVM = RT$. These results indicate a somewhat leaner explosive-limit for the lighter hydrocarbons (See Fig. 6) and are in general accord with the results found here for gasoline.

The following results have been reported for the lean limit of gasoline:

Per Cent by Volume	Observers	Reference
1.50	Burrell and Boyd	Bureau of Mines Tech. Paper 115
2.40	Martini and Hüneke	*Chemiker Zeitung*, Nov. 8, 1916, p. 948
2.94	Biluchowski and Lahocinski	*Petroleum*, February, 1914, p. 605; *Chemical Abstracts*, September, 1914, p. 3115

Burrell and Boyd obtained practically the same results, 1.5 per cent by volume, with two grades of gasoline of specific gravities at 60 deg. fahr. of 0.689 and 0.739. Their results, which were computed on the assumption that the fuel vapor had an average chemical composition equivalent to C_5H_{12}, are equivalent to an air-fuel ratio of about 26 which is in good agreement with the present experiments. Martini and Hüneke gave no detailed information as to the experimental basis for the values stated, namely 2.4 per cent for gasoline and 2.7 per cent for benzol. The value reported by Biluchowski and Lahocinski was taken from *Chemical Abstracts*, the complete paper being unavailable. The limiting mixtures given by these two sets of observers, corresponding to about 12 and 10 air-fuel ratio respectively, are so rich as to suggest that they may have been determined in rather narrow tubes.

Explosive-limit mixtures for a number of different motor fuels have been determined by W. G. Lovell, J. D. Coleman and T. A. Boyd. The results are reported in an article entitled A Laboratory Method of Determining the Starting Properties of Motor Fuels[8] in terms of air-fuel ratio supplied to a metal bomb at various temperatures. By combining their results at 0 deg. cent. (32 deg. fahr.) with data obtained on the same fuels with the equilibrium air distillation apparatus[9] it is possible to calculate lean explosive-limits as follows:

Fuel No.	2	3	6	7
Air-Fuel Ratio Supplied	7.0	1.4	1.8	8.4
Amount Evaporated, per cent	23.0	6.4	7.8	27.0
Air-Fuel Ratio Lean Limit	31	23	23	31

Data are also presented by Lovell, Coleman and Boyd which indicate systematic differences between the lean explosive limits for cracked and straight-run gasolines of practically identical volatility as indicated by their distillation curves. The limiting mixtures with cracked gasolines were found to be somewhat richer than the corresponding straight-run gasolines. The method used, however, was similar to the saturated-vapor method described in the first part of this paper, and their results are subject to the uncertainties due to surface effects there pointed out. Difference in adsorption on the walls or in solubility of the two types of fuel vapor in the unevaporated liquid remaining on the surfaces would introduce systematic differences in the observed results.

CONCLUSIONS

A method of determining the limiting explosive mixtures of air and fuel vapor has been developed and applied to numerous motor fuels. The data obtained indicate that a lean explosive-limit of 25 air-fuel ratio applies to quiescent mixtures of air and vapors of such fuels when ignited at the center of a closed bomb of sufficient capacity. This value was found to apply equally well to cracked and straight-run gasolines. It may be inferred from these results that, aside from volatility, there is probably no appreciable difference between the various kinds of hydrocarbon motor-fuel so far as usefulness in starting an engine is concerned.

INTEREST SHOWN IN SPARK AND VELOCITY EFFECTS

In the discussion following the paper, R. E. Wilson,[10] who presided as chairman of the session, said that experiments carried out by him and by D. P. Barnard, 4th, seemed to indicate that, with a small source of heat, velocity is probably a very serious factor, but that with an adequate source of heat the effect of velocity as related to mixture-ratio would be very much less important. Mr. Cummings agreed that a large heat-source such as a flame would probably lessen the difference between the static and the dynamic results, although within the limits of the experiments made, changing the length of the spark gap or the spark intensity did not appear to influence the lean explosive-limit appreciably.

Mr. Wilson also expressed the opinion that the effect of the spark would be greater at higher velocities than those employed. Mr. Cummings agreed that this might probably prove to be the case, although, within the range used in the investigation, the results were independent of spark intensity. Mr. Cummings added that the final values for the lean explosive-limit are those given in Table 3 and were obtained at zero velocity by the superheated-vapor method. The dynamic values by this method cover a considerable range of velocities but no very high velocities were used.

[8] See *Industrial and Engineering Chemistry*, March, 1927, p. 389.
[9] See THE JOURNAL, August, 1926, p. 151.
[10] M.S.A.E.—Assistant director of research, Standard Oil Co. of Indiana, Whiting, Ind.

RESEARCH COMMITTEE PROJECTS

Many Topics Discussed at Committee and Subcommittee Meetings at French Lick

A great variety of questions are presented to the Research Committee during the course of a year's activity. The discussion at meetings of the Research Committee and its subcommittees at French Lick Springs, Ind., during the course of the Semi-Annual Meeting exemplified the broad range of subject-matter covered.

One of the first items of business to come before the Research Committee was the consideration of four questions referred to it by the Operation and Maintenance Committee. The first of these was, Can a recommendation be made for practical specifications and test methods, both for lubricants and fuels, to be used by fleet operators who buy in tank-car lots, which will not be couched in highly technical terms and will be capable of application by junior operators?

The consensus of opinion at the meeting seemed to be that, so far as our present knowledge goes, no specifications for lubricants are available that can be universally applied and result in the provision of the proper lubricant for all of many different sets of conditions and purposes; and that test methods so far known are too highly specialized to yield accurate and dependable results in the hands of any but an expert operator.

The second question concerned the possibility of some investigation by the Research Committee into the construction and operation of mileage-recording devices. The importance to fleet operators of accurate mileage-records needs no emphasis, since the basis for comparing the results obtained by different vehicles and fleet operators is the mileage run by the vehicle.

The Operation and Maintenance Committee wished to know in the third place whether questionnaires prepared by it designed to elicit specific information of interest to fleet operators could be issued and the answers tabulated by the Research Department. The Research Committee was agreed that such service could be rendered by the Research Department.

Finally, the Operation and Maintenance Committee expressed the interest of fleet operators in investigations dealing with the economic phases of highway transportation, specifically in questions pertaining to the design of the vehicle, the design of the highway and the use of the vehicle on the highway. It was pointed out that the Society is represented through the Research Committee and its subcommittees in such organizations carrying out highway-research projects as signify a desire for our cooperation. Reports on progress made and final conclusions are printed in THE JOURNAL.

Questions Affecting Fuel Research

A question that has been asked of the Research Department a number of times recently, especially by tractor operators and manufacturers, is, What are the proper specifications for engine distillate? The opinion generally expressed was that no exact definition of engine distillate is possible; that, in general, engine distillate is the scrap-heap of the refinery, made up of residues left over that cannot be included in the other carefully made products; and that it therefore has no stable characteristics.

Information regarding the detonation survey being carried out at the Bureau of Standards as part of the Cooperative Fuel-Research was given to the Research Committee. In the first part of this survey 15 fuel samples were collected from various oil companies and analyzed. The aim of the second part of the survey was to answer as nearly as possible a question raised at a former meeting of the Research Committee, What type of fuel from an antiknock standpoint is available to the motorist? Present plans, subject to the approval of the Cooperative Fuel-Research Steering Committee, call for the publication of the results of this survey when it is completed.

A symposium on sulphur in motor fuels is to be held in connection with the meeting of the American Chemical Society in December of this year. The Research Committee was requested to make and did make suggestions of possible participants in the symposium. A final question with reference to fuel and its uses was that concerning ozone in garages and repair-shops. In this connection it was suggested that a search be made through the literature of the subject and that an item be inserted in THE JOURNAL summarizing the published data on it.

Topics Proposed by Committee Members

Research Committee members had submitted a number of topics thought to be of interest as either subjects of investigations or of papers for Society meetings. The Research Committee instructed the Research Department to handle the questions arising in this connection, to gather information on the topics both from the literature and from men familiar with the various subjects, to pass this information on to members of the Research Committee and to take whatever action seems advisable.

Some of the topics were: The efficiency of engines; the behavior of gasoline-air mixtures in manifolds; the desirability of establishing a standard procedure for chassis-dynamometer testing; the proper size and shape of fillets; the direct correlation between work in the industry and the technical schools; and suitable properties of iron casting for automotive use.

Riding-Qualities Instrumentation

Instrumentation for riding-qualities constituted the chief topic of discussion at the meeting of the Riding-Qualities Subcommittee. R. W. Brown, of the Firestone Tire & Rubber Co., described briefly a six-element contact-type accelerometer that is now being made on a production basis. The object in developing this instrument was to design a practical usable device that would give results of sufficient accuracy to be valuable, and at the same time be rugged enough to be applied to truck, motorcoach and passenger-car axles.

H. K. Cummings described an investigation into the riding-qualities of ambulances carried out by the indicator developed by the Bureau of Standards. The instrument comprises a contact accelerometer and an electrolytic cell for adding up the short time-intervals during which the electric contact is broken. The accelerometer consists of a weight supported by a tension spring, the tension of which may be adjusted with a calibrated micrometer-head. When this spring is set so that an upward acceleration of, say, $\frac{1}{2}g$ will separate the electric contact, the electrolytic cell indicates the total time during which the upward accelerating force exceeds any value for which the instrument is set, for instance, $\frac{1}{2}g$. This indication may be stated in percentage of the total time. The accelerometer may be placed on the floor, the seat cushion or elsewhere.

Other topics covered in the meeting were the adjusting of shock-absorbers to give the best riding-qualities on various types of road; cooperation with the Special Research Committee on Mechanical Springs of the American Society of Mechanical Engineers; and an analysis of the contact-type accelerometer prepared by Dr. Benjamin Liebowitz.

Headlight Research Furthered

Two meetings affecting headlight investigations were held; one, that of the Joint Steering Committee on Headlight Research; the other that of the Headlight Subcommittee of the Research Committee of the Society.

At the former meeting the main topic was the test program designed to elicit the opinion of car and lamp manufacturers as to what may be considered ideal light-distribution. Many owners of the test equipment which has been developed to carry out this investigation were present. A preliminary problem presented to the experimenters was printed in the June issue of THE JOURNAL on p. 690. The details involved in its execution were discussed, as well as desirable points to be included in future problems.

Dr. Dickinson touched briefly on some of the features of the headlight research being carried out at the Bureau of Standards under the joint sponsorship of the National Automobile Chamber of Commerce and this Society. It is proposed at the Bureau to make a systematic study of the types of light distribution required for safe and satisfactory visibility on the different classes of road under all usual driving conditions, with a view first to optimum illumination, in the absence of opposing traffic; and second when meeting other vehicles. For this purpose, two sets of the test equipment had been purchased, so that two cars suitably equipped could be used in studying passing conditions. The two types of light distribution, the high-speed-driving light and the low-speed passing-light will be studied. The method will be to set up a test object and to record the various distances at which it becomes visible under various conditions with various light distributions.

Whether or not the Society should endorse a resolution passed by the Committee on Motor-Vehicle Lighting of the Illuminating Engineering Society at a meeting held on April 13 was considered by the Headlight Subcommittee. At this meeting, at which representatives of the Society were present, some discussion was had concerning the headlight project of the American Engineering Standards Committee, sponsored by the two Societies. The resolution read in part

> That, if the practice of the American Engineering Standards Committee requires it, the Illuminating

Engineering Society is agreeable to the discontinuance of the project and discharge of the sponsors, with the understanding that as soon as it appears practicable to formulate an acceptable extension of the standard, the Illuminating Engineering Society will request the establishment of such project and appointment of the same sponsors.

The Headlight Subcommittee endorsed this resolution and referred it for further action to the Council of the Society, which approved it at a meeting that was held subsequently.

The Headlight Subcommittee also reported its approval of the statement prepared by H. M. Crane, chairman, for inclusion in the annual report of the Committee on Production and Application of Light of the American Institute of Electrical Engineers. This statement was published in the May issue of THE JOURNAL on p. 570. The final topic considered was the invitation extended to the Headlight Subcommittee by the Metropolitan Section to present a headlight demonstration at the September Meeting of that Section.

CORRECTION

Some inaccuracies were unfortunately included in Table 1 of the paper entitled Carbon-Depositing Tendency of Heavier Motor-Oils, by C. J. Livingstone, Samuel P. Marley and W. A. Gruse, published in the June issue of THE JOURNAL on p. 689. The correct version of the table is given below.

TABLE 1—PROPERTIES OF THE OILS USED

Oil	Blend *A*	Distillate *A*	Blend *B*	Distillate *B*
Gravity at 100 Deg. Fahr., American Petroleum Institute deg.	24.5	19.8	23.8	18.5
Cold Test, deg. fahr...	30	5	45	10
Viscosity at 210 Deg. Fahr., Saybolt sec..	60	61	85	80
Flash-Point, deg. fahr.	415	385	440	415
Fire-Point, deg. fahr..	450	420	515	465
Conradson Carbon, per cent	0.92	0.22	1.48	0.22

FOREIGN LOANS

IN thinking of our foreign loans we are apt to visualize loans to Europe. But Europe has taken only a little more than one-fourth of the American capital invested abroad. A larger amount has been loaned to South America and nearly as much to Canada. Of the total Latin America has had \$4,700,000,000; Europe, \$3,200,000,000; and Canada, \$3,100,000,000. During all of last year a general feeling prevailed that this expansion of American financing in foreign countries was coming to an end, but actually no evidence of this has been seen. The indications are that the total for the present year is likely to surpass former records.

Of course these debts of foreign countries differ materially from those owed by the Allied governments to the United States Government. The proceeds have gone largely toward building up industries that have become profitable by reason of augmented capital, without which they never could have been undertaken. Reliance, thus, for eventual payment is placed upon the earning power and prosperity of the enterprises themselves.

The source of the power to make these great loans abroad lies of course in the increased national income which, according to the National Bureau of Economic Research, reached the sum of \$90,000,000,000 in 1926, an increase of approximately \$27,000,000,000 in 5 years. This income is widely distributed among the people. Only 74 people in 1923 had incomes of \$1,000,000 or more and the last returns show that 207 persons had such incomes, but only 321,146 persons had incomes of \$10,000 or more. This leaves the majority of the other billions of income distributed among a vast number. An average income of over \$2,000 for each person gainfully employed is estimated and accounts for our high standard of living; the highest for the population, as a whole, ever reached in any country.

A very important part of our prosperity is undoubtedly due to the greater efficiency of labor, or at least the increased output per worker, as shown in the latest census report comparing 1923 and 1925. The figures given relate only to manufacturing establishments, the number of which between the 2 years noted decreased by 4 per cent and the average number of wage earners employed dropped about the same percentage. But the workers received more pay and did more work.—*Bache Review.*

PRODUCTION ENGINEERING

(*Concluded from p.* 12)

izing the report a further study of the requirements of the industries should be made. The sentiment of the members of the Subcommittee was also strongly in favor of developing a new standard, to be known as the American Machine-Taper, that could be adopted simultaneously by all manufacturers. Such a standard, if feasible for this class of work, would avoid either the setting up of a variety of tapers in the standard, or the general adoption and use of a series of tapers that has been set up by one manufacturer.

To facilitate further study of this project, it was decided by the Subcommittee to send out a questionnaire, particularly to users of machine-tools, to ascertain whether one standard taper is preferred; whether the ¾-in.-to-the-foot taper would meet with general approval; whether the 6/10-in.-to-the-foot taper would be preferable; or whether it is thought that two standard series are necessary, and, if so, what series should be established. The Subcommittee was increased by adding more user-representation, and the questionnaire will be circulated first among the members of the new Subcommittee, after which, if it seems satisfactory, it will be distributed generally to the industry.

Inasmuch as the standardization of machine tapers is one of the most important projects for standardization on a National basis that has developed so far in this class of work, it is brought specially to the attention of the production engineers and executives in the automotive industry for their study and constructive consideration, as this industry is without doubt the largest consumer of machine-tools and machine-tool parts. It is not contemplated that the standards when completed will be intended primarily for use in automotive products but they may be so used where conditions would warrant it in the opinion of the individual producers. This project should not therefore be confused with the standard tapers that have already been established and are in extensive use for the product. Constructive suggestions regarding this project or bearing on the tapers themselves may be sent to the Society's office, where they will be referred to the Subcommittee.

Effect of Wet Roads on Automotive Headlighting

By R. E. Carlson[1] and W. S. Hadaway[2]

Semi-Annual Meeting Paper *Illustrated with* Photographs

ABSTRACT

LABORATORY and road tests of headlighting on dry and wet road-surfaces, with various types of head-lamp beam, are described and the effects obtained are shown pictorially and data are given statistically. The test equipment and the conditions of the tests are described. Strength of the beam was controlled and the photographs were made under standard conditions so that results would be comparable.

Results obtained show that depressing the beam of a depressible-beam head-lamp when an asphalt or concrete road-surface is wet greatly increases the apparent intensity of the beam above the road, evidently due to reflection from the road surface, and that this intensity extends far above the horizontal height of the head-lamp, thereby defeating the object of depressing the beam.

With a non-symmetrical beam, produced by a two-filament lamp, disposed so that the beam is directed straight ahead from one filament but can be shifted to the right by switching to the other filament, very little light is projected into the region in which the eyes of an approaching driver would be located. This effect can be produced by using an auxiliary driving-light aimed to the right of the axis of the car.

When two facing cars both used the upper beam of a depressible-beam head-lamp, on a wet asphalt road, a target 3 ft. from one car and 3 ft. above the road was visible at the maximum distance of 67 ft. With both cars using the non-symmetrical beam aimed to the right, the target was visible at 159 ft., and when placed near the right-hand curb was visible at 313 ft.

Conclusions deduced from the tests are that (*a*) wet road-surfaces change the light-distribution materially, resulting in greater glare; (*b*) more light-intensity is required to reveal an object on a wet road, due to interference with vision and change in light-distribution; (*c*) increasing the light-intensity in a symmetrical system does not improve visibility; (*d*) a non-symmetrical system in which the high-intensity portion of the beam is directed to the right of the car axis reduces glare and allows better vision; (*e*) use of two 21-cp. lamps does not give sufficient light-flux for all requirements; (*f*) use of a wide-spread low-intensity beam near the car, in combination with a relatively narrow controllable high-intensity driving-beam has advantages for both dry and wet roads; (*g*) no reason is known why a fixed-focus design should not be used with a somewhat longer focal-length than at present, with suitable reflectors or lenses for the low-intensity beam; and (*h*) the use of auxiliary driving-lights with the beam directed to the right should be encouraged.

AN investigation undertaken to obtain information on the effect of wet road-surfaces on road lighting produced by automotive driving-lights, as described herein, was conducted in the laboratory and on the road, with several symmetrical and non-symmetrical lighting-systems. An endeavor was made in the laboratory to obtain photometric and photographic records of the change in light-distribution resulting from use of a wet surface. On the road the effect of the wet road-surface on the ability to see was studied, as well as the comparative efficiency of different systems of light-distribution as regards visibility. We are indebted to L. C. Porter, in charge of the special development section of the Edison Lamp Works, for permission to include in this paper information which he obtained in a separate investigation made in the autumn of 1926 concerning the effect of water on the lenses and the effect of wet road-surfaces on the beam intensity as actually measured on the road at different test stations.

The type of test equipment used in the laboratory and for test car No. 1 on the road is shown in Fig. 1. It consists of two pairs of specially constructed head-lamps mounted on a steel bar and suitable control mechanism consisting of switches, rheostats and ammeters. The face of the control unit is shown in the photograph at the right. Rheostats of the carbon-pile type are used for current-regulation. By suitable switches either the upper or lower filament of a particular lamp or pair of lamps can be lighted, and provision is also made for auxiliary lamps. Separate rheostats are provided for dimming. A separate two-unit battery was used in connection with this control unit.

The construction of a head-lamp unit is shown in Fig. 2, which illustrates particularly the micrometer focusing-mechanism employed, which makes possible the accurate positioning of the lamp filament through vertical or horizontal movement or through rotation of the filament. Either single or double-filament lamps can be used. The lenses are held in the head-lamp door by special rings designed to facilitate change of lenses. This equipment was designed and developed by L. C. Porter, of the special development section, and W. S. Hadaway, of the automotive lighting section, of the Edison Lamp Works.

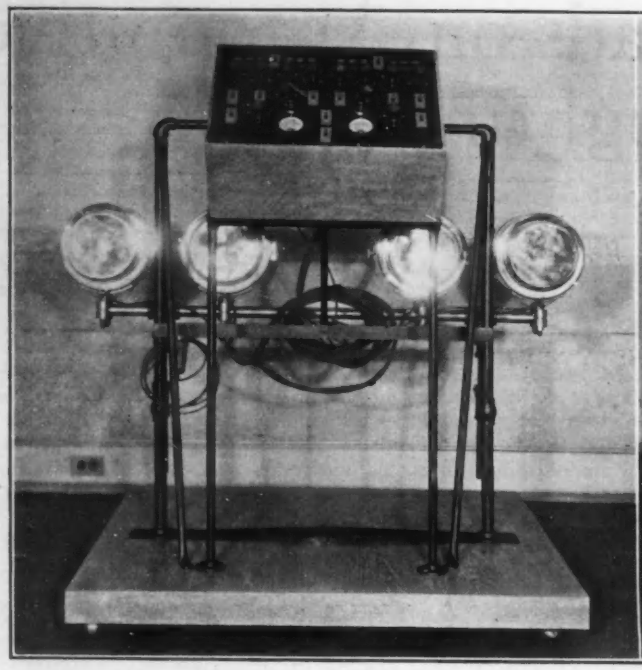
A standard portable photometer was used to make photometric readings on the screen in the laboratory and in the garage. On the road, the British Engineering Standards Association test-disc was used to give a comparative indication of the ability to see under the different test conditions. Adjustment of head-lamps was checked in the garage under standard conditions with a screen so that any desired light-distribution could be reproduced with a fair degree of accuracy.

Results Obtained from Laporatory Work

In the laboratory, an endeavor was made to record, by photometric measurements and photographs, the change in distribution in the beams which occurred when the light was directed over a wet surface instead of a dry

[1] M.S.A.E.—In charge of automotive lighting, Edison Lamp Works of the General Electric Co., Harrison, N. J.

[2] Automotive lighting section, Edison Lamp Works of the General Electric Co., Harrison, N. J.



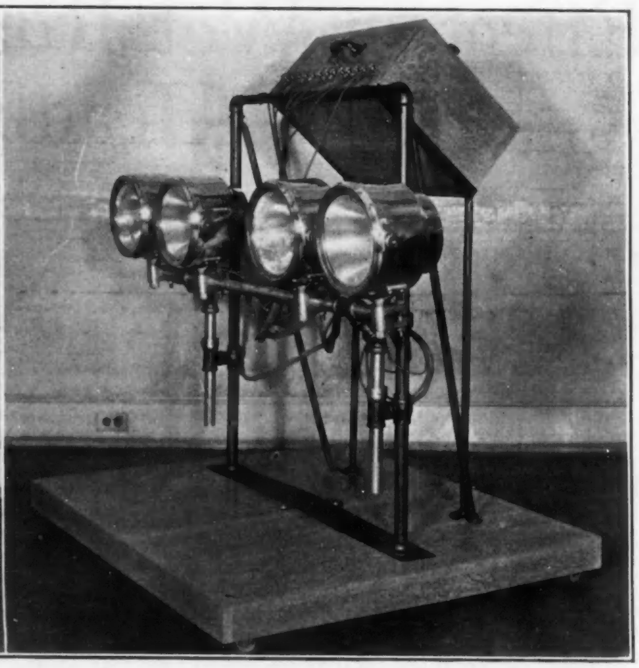


FIG. 1—HEADLIGHTING TEST-EQUIPMENT USED IN LABORATORY AND ON TEST CAR NO. 1 ON THE ROAD
Two Pairs of Specially Constructed Lamps Are Mounted on a Bar as Shown and Are Controlled by Switches, Rheostats and Ammeters Contained in the Case Above. Either Upper or Lower Filaments of a Particular Lamp or Pair of Lamps Can Be Lighted at Will, and Provision Is Made for Auxiliary Lamps. Separate Rheostats Are Provided for Dimming

concrete-floor. The test equipment was set up in the basement of one of the buildings having a concrete floor and the screen shown in the accompanying illustration was placed at distances of 57 and 85 ft. respectively from the head-lamp. Only one head-lamp was used, therefore the values of apparent beam-candlepower given are for

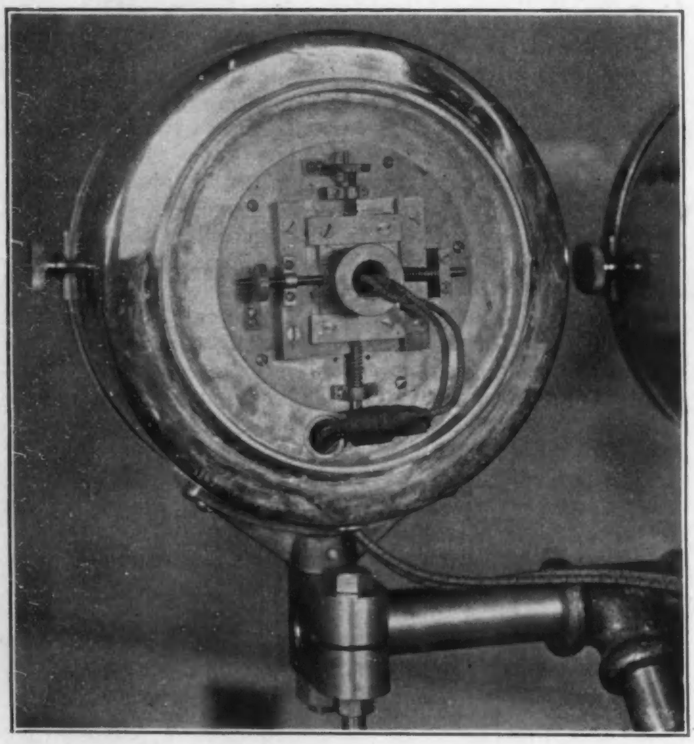


FIG. 2—SPECIAL HEAD-LAMP WITH MICROMETER FOCUSING MECHANISM
Accurate Positioning of the Filament by Vertical or Horizontal Movement or by Rotation Is Made Possible by the Focusing Mechanism. Either Single or Double Filament Can Be Used. Lenses Are Held in the Head-Lamp Door by Special Rings That Facilitate Change of Lenses

one 21-cp. incandescent lamp and head-lamp unit only. The term "apparent beam-candlepower" is not strictly accurate in some of the measurements because all of the light does not come directly from the beam, a part being reflected from the floor. The lines on the screen are 1 ft. apart, which spacing corresponds, at a distance of 57 ft., to 1 deg. Photometric readings and photographs were taken for all of the approved types of depressible-beam equipment but, to save space, data are given for only one of the typical equipments.

The upper left photograph in Fig. 3 shows the upper beam from one head-lamp of the depressible-beam type when directed on the test screen, placed 57 ft. in front of the lamp and with the concrete floor dry. The lamp was focused and then aimed so that the upper cut-off line was the same distance above the floor as the head-lamp. The center of the head-lamp was 3 ft. above the floor and the cut-off of the beam was adjusted to come just below the third line from the bottom of the screen. It will be noted on the screen that this beam complies with standard specifications.

Using the same upper-beam but with the concrete floor wet gave the result shown in the upper right exposure. The wetting was done with a hose and an attempt was made to obtain a constant amount of wetness. As will be observed, the candlepower values in the beam are increased considerably, no doubt due to increased reflection from the lower part of the beam. The beam pattern is also spread out somewhat and is not so uniform as in the preceding figure.

The lower left and right exposures show respectively the lower beam with floor dry and with floor wet. From these two photographs it will be noted that with the wet floor the beam is made very spotty and the values for apparent candlepower are greatly increased higher up in the beam.

Effects of using the upper beam, with the screen located at 85 instead of 57 ft., and with the floor dry and wet, respectively, are shown at the upper left and right in

Fig. 4. As the height of the head-lamp above the floor is three spaces from the bottom of the screen, it will be noted that the effect of the wet floor-surface under this condition is to produce a beam which greatly exceeds the allowable limits above the horizontal. As at the upper right in Fig. 3, the wet floor also increases the intensity in the central portion of the beam. The lower views in Fig. 4 show the lower beam with the screen located at 85 ft. from the lamp. In that at the left, taken with a dry floor, the relief afforded oncoming drivers by beam depression is apparent, as very little light is thrown on the screen. In that at the right, taken with a wet floor, it will be seen that the conditions defeat the object of depressing the beam, because intensities on the order of 2000 to 3000 cp. are shown above the horizontal and in the region through which the approaching driver must pass. This region extends from 150 ft. ahead of the lamps to 60 ft. from the lamps.

The effect of pools of water on the road are revealed in Fig. 5. The intensity in the spot is 4600 apparent candles, whereas the intensity of the surrounding area is 1650 candles.

Effects of Shifting Beam to Right

The effect of a wet surface on a beam aimed so that almost no light would be thrown to the left of the car axis is shown in Fig. 6, in which case the screen is located 85 ft. from the head-lamp. A beam of this type might be obtained by the use of an auxiliary driving-light aimed to the right of the car axis. Very little light is thrown into the left half of the screen in the section in which the eyes of an approaching driver would be located.

A method of beam control through the use of a two-filament lamp in which the beam is shifted to the right by switching from one filament to the other is illustrated in Fig. 7, in which the right view shows the beam shifted to the right and the floor wet.

Comparison of this with the lower right view in Fig. 4 of a depressed beam on a wet surface at 85 ft. is of interest as indicating the reduction in the amount of light which would be projected into the eyes of oncoming drivers by the latter beam.

Water on Lens Diffuses Beam

The effect of water on the surface of several types of lens has been investigated by L. C. Porter, who used a water-spray equipment consisting of pipe having a row of small holes drilled along its length so that the water would cover the surface of the lens. These tests indicate that the water spray acts to diffuse the beam, the concentrated portion becoming less defined and tending to spread. A decided loss in candlepower occurs at points *A*, *B*, *C*, P_l and P_r in the Illuminating Engineering Society specifications. For point *D* the candlepower for one lens tested remained virtually unchanged when the lens was wet, but for two other types of lens the value at this point increased to exceed the specifications.

The results of laboratory tests on the depressible-beam type of equipment indicated that relief, as measured by the intensity of light thrown into the glare region, was not afforded by depressing the beam when used on a wet concrete-floor. The use of a non-symmetrical system, in which the high-intensity portion of the beam was di-

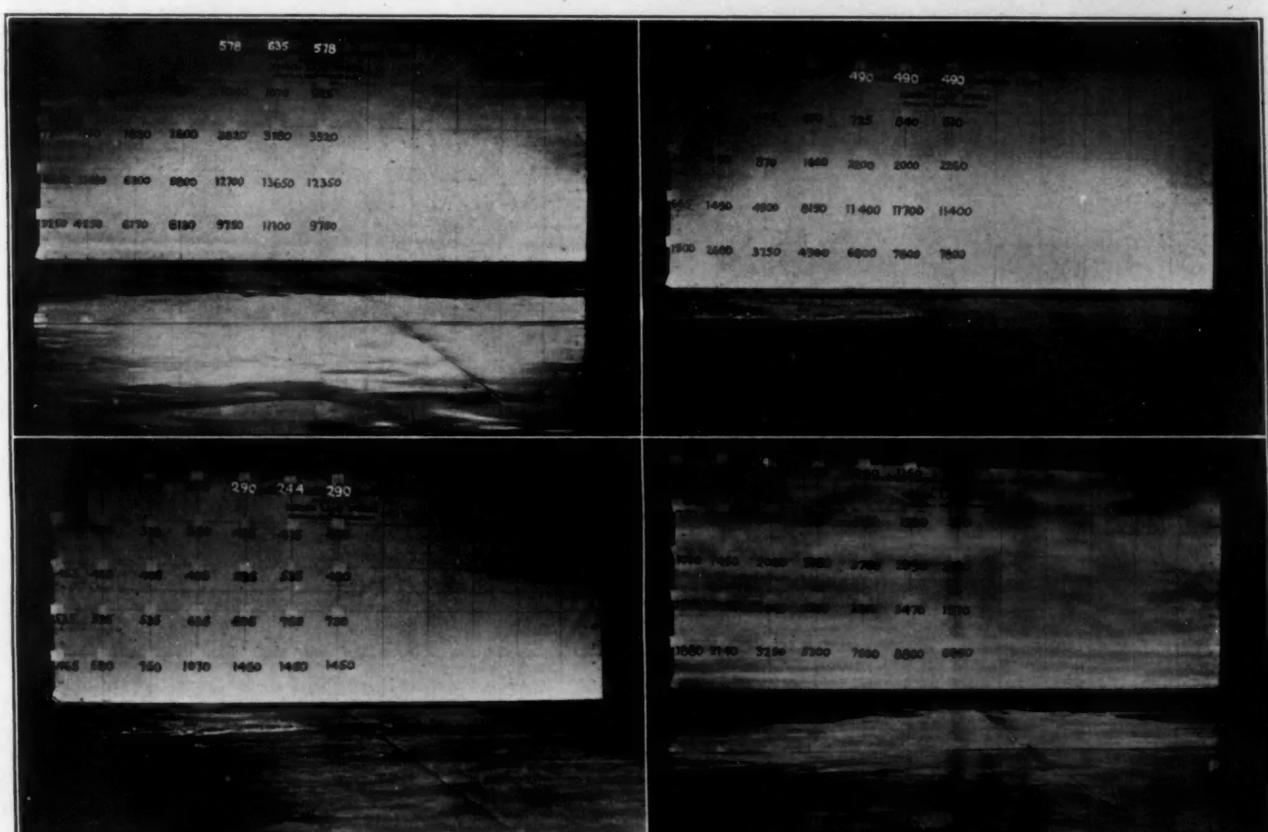


Fig. 3—Light-Distribution on a Screen in a Garage with Dry and Wet Concrete-Floor Using Upper and Lower Depressible-Beam

The Screen Was Located 57 Ft. from the Lamp and the Numbers Indicate the Apparent Beam-Candlepower. The Beam Was from One Head-Lamp. The Upper Left View Shows the Effect with the Upper Beam and a Wet Floor, and the Upper Right View Shows the Effect of the Same Beam with a Dry Floor. The Lower Left and Right Views Show Respectively the Effect of the Lower Beam with Dry and Wet Floor. Reflection from the Wet Floor Greatly Increased the Intensity of Light on the Screen, and Distribution of the Light Was Not So Uniform as with the Floor Dry

rected to the right of the vertical center line, did give the desired relief.

How the Road Tests Were Made

The object of the road work was to secure information on the effect of wet surfaces on the ability of the driver to see when using and when meeting different types of light-distribution. Two test cars were used, No. 1 equipped with the head-lamps and control apparatus described, and No. 2 equipped with the S.A.E. test-equipment and, in addition, a pair of typical depressible-beam head-lamps. The road work was carried on in Harrison, N. J., on a wide level asphalt street which carried very little traffic and had no street lighting. White cardboard markers were placed along the curbs as shown in the photographs, spaced 40 ft. apart, except the last marker on the right, which was spaced 80 ft. from the next one because of a road intersection. Relative location of the cars on the road is shown in Fig. 8, in which test car No. 1, located near the left curb, has the cowl lamps lighted. The photographs and observations were taken from test car No. 2, located in the middle of the road facing car No. 1. The British Engineering Standards Association disc was placed 3 ft. out from the rear of car No. 1 and 3 ft. above the road surface.

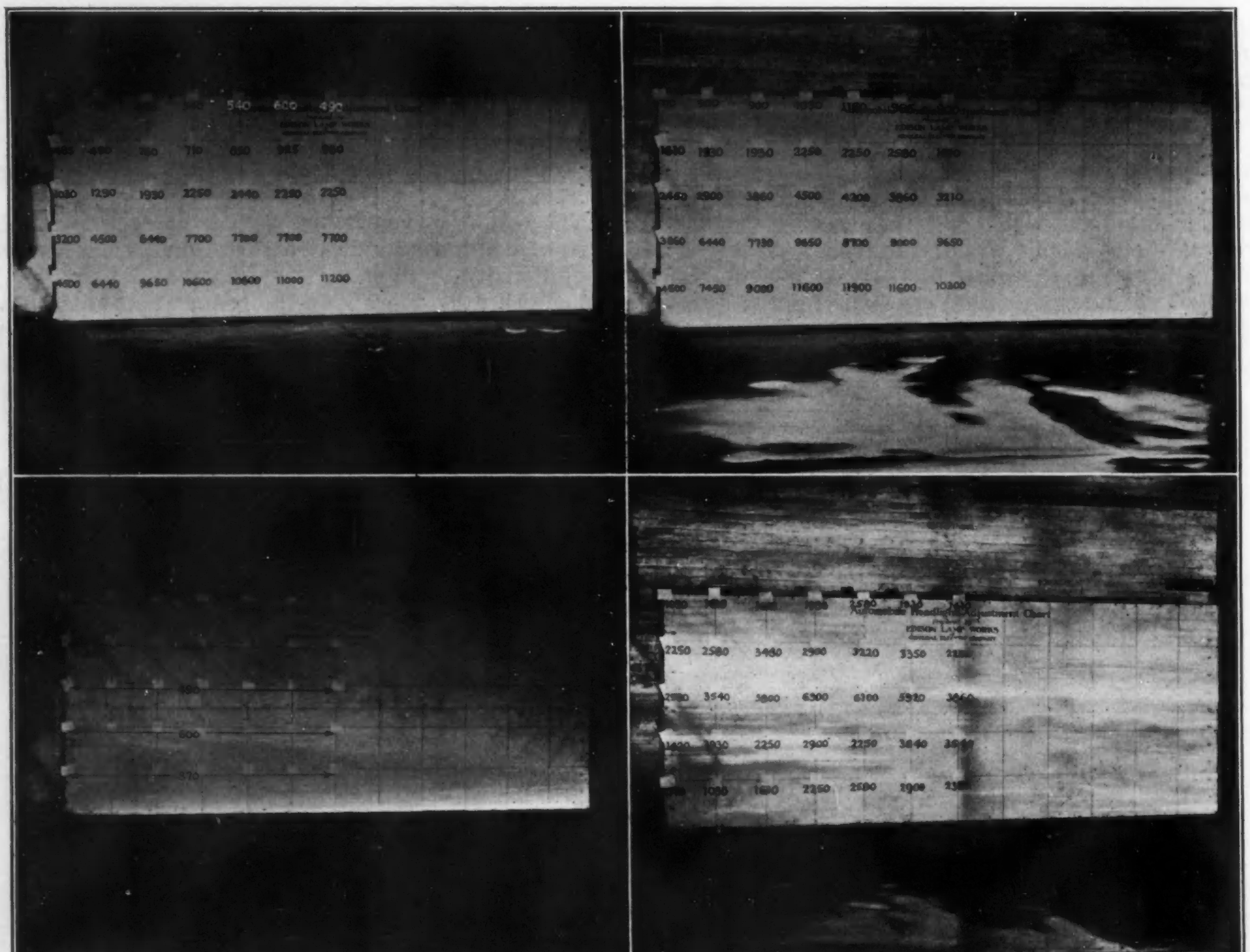


Fig. 4—Light-Distribution with Screen Located 85 Ft. from the Lamp
The Upper Left and Right Views Show Respectively the Effect of the Upper Beam from One Depressible-Beam Lamp with Dry and Wet Floor, and the Lower Left and Right Views Show the Effect of the Lower Beam under Similar Conditions. The Wet Floor Produces a Beam That Greatly Exceeds the Allowable Limit above the Horizontal Height of the Head-Lamp, Which Is Indicated by Three Spaces on the Screen above the Floor. This Fact, Together with the Great Increase in Intensity, Defeats the Object of the Depressible Beam When the Road Is Wet

The distribution of light on the road from the upper beam of the depressible-beam head-lamps on car No. 2 is seen on the road. Distribution from the lower beam on car No. 2 is shown at the upper left in Fig. 9, and that from a non-symmetrical system, in which the light is directed to the right of the car axis, is seen in the upper right. When this beam is thrown on the screen in the garage, the intensity in the left 5 deg. of the beam is approximately 50,000 candles and the intensity in the right portion is approximately 25,000 candles.

The several systems were used to obtain comparative data on the ability to see the test disc when meeting and using different light-distributions. The light output from the two 21-cp. lamps on each test-car was held constant by current adjustment. Observations were also made with the head-lamps dimmed to 4 cp. and using an auxiliary 21-cp. driving-light equipped with a lens giving an 8-deg. spread aimed to throw the beam to the right of the car axis.

Results shown in Table 1 were obtained in a light drizzling rain, with the road surface wet. Photographs of many of the tests were taken but only a few are reproduced. A standard schedule for exposure, developing and printing was followed in all cases to assure comparative results. The lower left view in Fig. 9 corresponds to

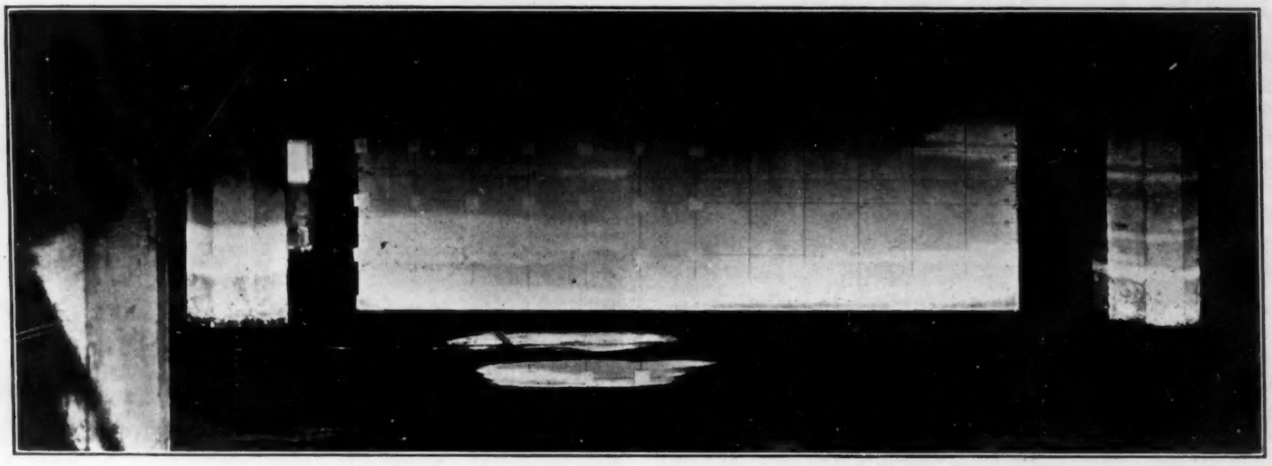


FIG. 5—EFFECT OF POOLS OF WATER ON THE DEPRESSED BEAM
Intensity of the Spot of Light Reflected on the Screen from the Wet Floor is 4600 Apparent Candles, Whereas That of the Surrounding Area Is only 1650 Candles

test No. 1 in the table, and the lower right view to test No. 8. In the photographs the cars were located 160 ft. apart. The distances at which the test disc was visible, as given in the table, represent the average of several trials under each condition. Observations were made from the seat of test car No. 2, the car being moved along the middle of the road toward car No. 1 until the target was visible.

TABLE 1—VISIBILITY ON WET ROAD WHEN MEETING AND USING VARIOUS LIGHT-DISTRIBUTIONS

	Light-Distribution Used on Test Cars		
Test No.	Test Car No. 1, Approaching Car	Test Car No. 2, Observation Car	Test Target Visible at, Ft.
1	Upper Beam	Upper Beam	67
2	Upper Beam	Lower Beam	54
3	Lower Beam	Upper Beam	66
4	Lower Beam	Lower Beam	51
5	Upper Beam	Non-Symmetrical	120
6	Non-Symmetrical	Upper Beam	141
7	Non-Symmetrical	Lower Beam	84
8	Non-Symmetrical	Non-Symmetrical	159
9	Head-Lamps Dimmed, 1 Auxiliary Driving-Light	Upper Beam	105
10	Head-Lamps Dimmed, 1 Auxiliary Driving-Light	Lower Beam	75
11	Head-Lamps Dimmed, 1 Auxiliary Driving Light	Head-Lamps Dimmed, 1 Auxiliary Driving-Light	84

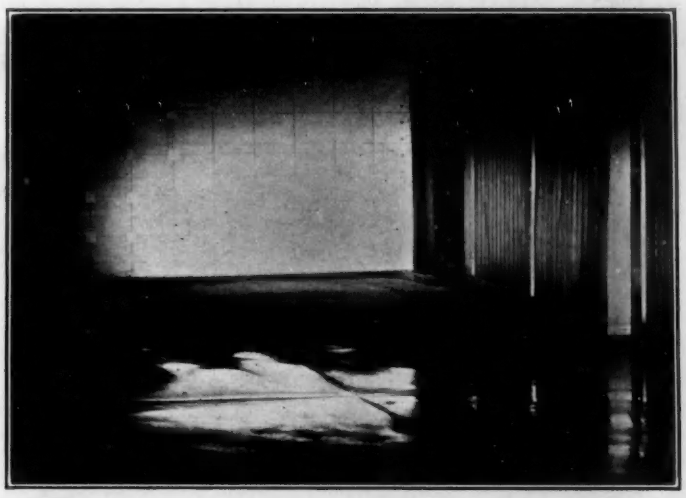


FIG. 6—EFFECT PRODUCED BY A WET SURFACE ON A BEAM SHIFTED TO THE RIGHT
Very Little Light Is Thrown into the Left Half of the Screen in the Portion in Which the Eyes of an Approaching Driver Would Be Located. A Beam of This Type Might Be Obtained from an Auxiliary Driving-Light Aimed to the Right of the Car Axis

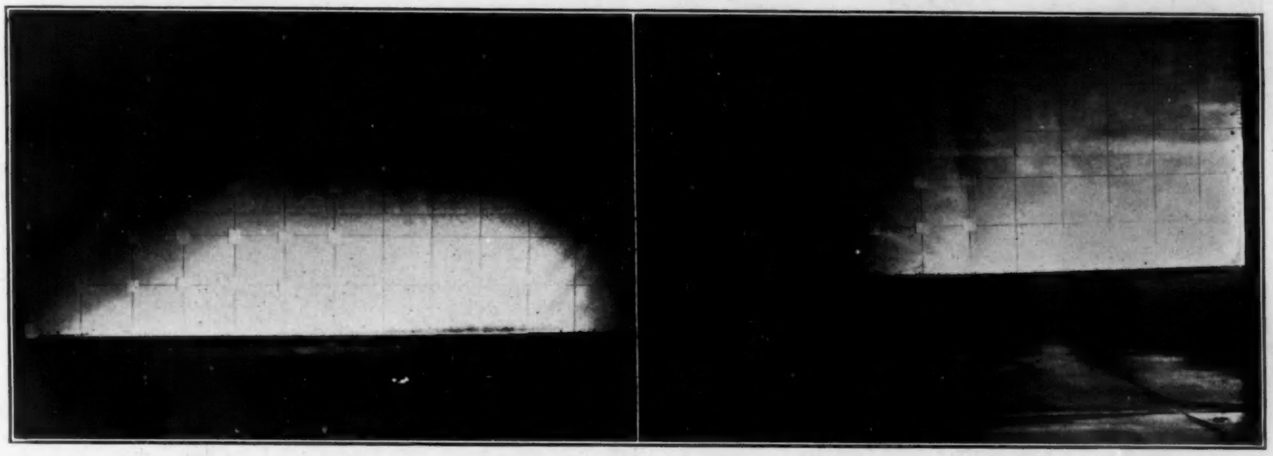


FIG. 7—BEAM CONTROL WITH TWO-FILAMENT LAMP IN WHICH THE BEAM CAN BE SHIFTED TO THE RIGHT
At the Left the Beam Is Directed Straight Ahead and the Floor Is Dry. The Right View Shows the Illumination with the Beam Shifted to the Right, by Switching Current to the Other Filament, and with the Floor Wet. Very Little Light Would Be Projected into the Eyes of an Oncoming Driver by This Latter Beam

Beam Directed to Right Increases Visibility

Study of the data given in Table 1 indicates that when using a given distribution on car No. 2, changing from upper to lower beam on the approaching car, No. 1, seemed to have little effect on the ability to see the target; that is, the interference with vision was not reduced. Changing from a symmetrical to a non-symmetrical system on Car No. 1 resulted in a reduction of glare and its consequent interference with vision, as indicated by the greater distance at which the target could be seen. By comparison with the standard system, a system which directs the light to the right of the car axis is less glaring and also permits a better view of the right portion of the road. Comparison of the lower left and right photographs in Fig. 9 shows the better illumination of the right side of the road resulting from the higher intensity directed to the right in the non-symmetrical beam, and also relatively the order of magnitude of the glare produced.

In test No. 6, on a dry road, meeting a non-symmetrical beam and using the upper beam, the target could be seen at a distance of 165 ft. when located at the car and up to 200 ft. when located at the right curb. On a wet road the target located at the car was visible at a distance of 141 ft. In test No. 7, using the lower beam, the target located at the car was visible at a distance of 90 ft. and up to 45 ft. at the right curb. On a wet road the target at the car was visible at 84 ft. In test No. 8, using a non-symmetrical beam, the target was visible at 195 ft. at the car and up to 313 ft. near the right curb. On a wet road the target at the car was visible at 159 ft. This is of interest as it shows the reduced visibility of the test target and right

Fig. 8—Road Arrangement for Testing Head-Lamp Illumination and Glare

Test Car No. 1, the Approaching Car, at the Curb on the Left, Has the Cowl Lamps Lighted. Photographs Were Taken from Test Car No. 2 in the Middle of the Asphalt Road. Markers Were Placed along the Curbs at 40-Ft. Intervals, and a British Engineering Standards Association Disc for Determining Visibility Was Placed 3 Ft. out from the Rear of Car No. 1 and 3 Ft. above the Road Surface. Distribution of Light from the Upper Beam of a Depressible-Beam Head-Lamp on Car No. 2 Is Shown

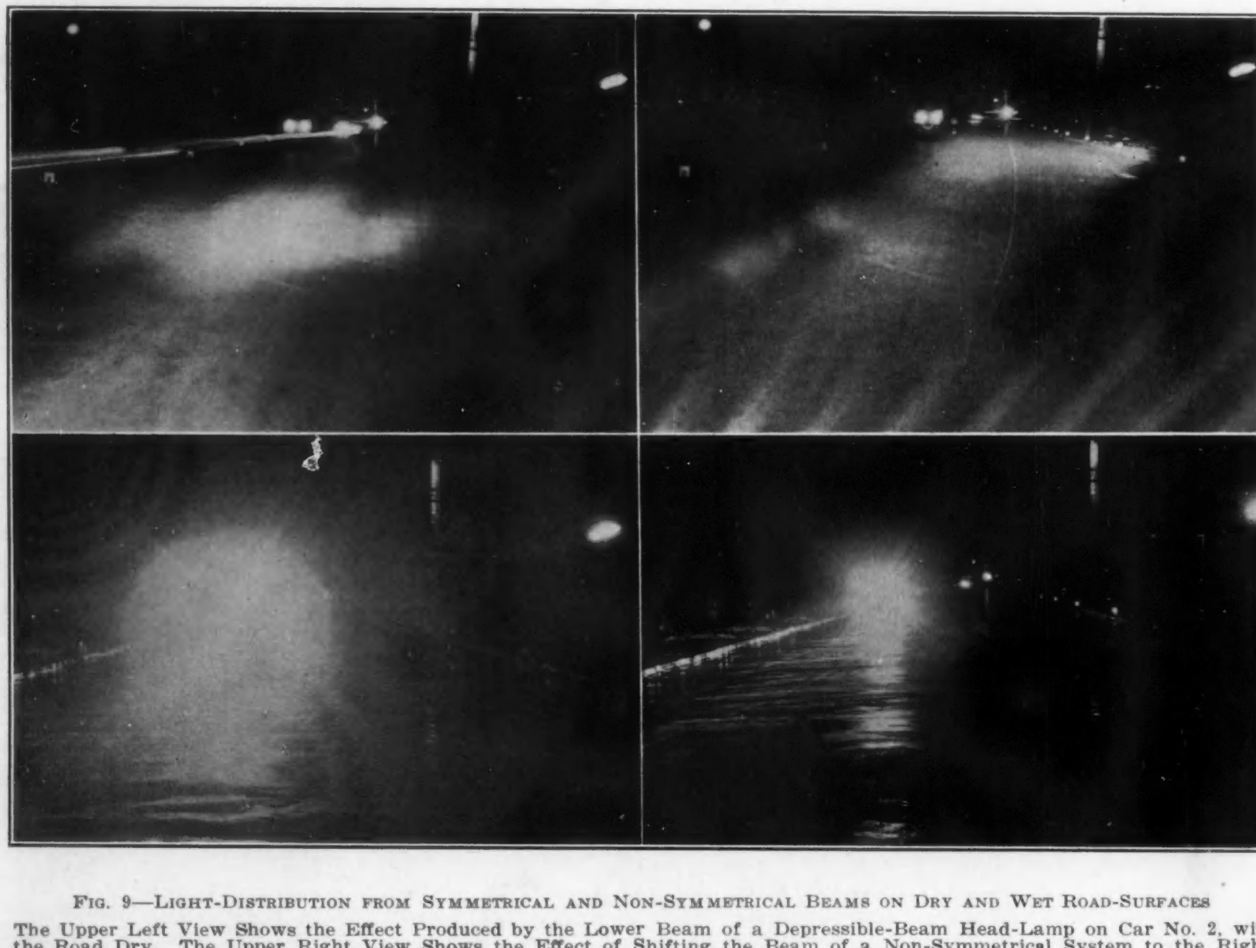


Fig. 9—Light-Distribution from Symmetrical and Non-Symmetrical Beams on Dry and Wet Road-Surfaces

The Upper Left View Shows the Effect Produced by the Lower Beam of a Depressible-Beam Head-Lamp on Car No. 2, with the Road Dry. The Upper Right View Shows the Effect of Shifting the Beam of a Non-Symmetrical System to the Right, So That the Approaching Driver Will Not Be Troubled by Glare. In the Lower Left View Both Cars Are Using the Upper Beam of a Symmetrical System and the Road Is Wet. This Corresponds with Test No. 1 in Table 1. In the Lower Right Both Cars are Using the Non-Symmetrical Beam Aimed to the Right and the Road Is Wet. This Corresponds with Test No. 8 in Table 1. The Cars Are Located 160 Ft. Apart. With Both Cars Using the Upper Beam, the Test Target Was Visible on a Wet Road at the Maximum Distance of 67 Ft., Whereas with Both Using the Non-Symmetrical Beam It was Visible at 159 Ft. alongside of Car No. 1 and at 313 Ft. When Placed near the Right Curb

curb due to the wet road as well as the increased glare.

Photometric measurements on both asphalt and concrete roads, made by Mr. Porter to show the effect of a wet road on intensity of both the upper and lower beam and to compare the two types of road surface, indicate relatively the same effects noted in the laboratory work described but show little difference between the effects of a concrete and an asphalt road-surface. From this work Mr. Porter concludes that most of the reflection comes from the surface of the water which, in the case of concrete, fills up the depressions.

Good Results with Auxiliary Driving-Light

In endeavoring to set up a system of light-distribution which would give satisfactory results as regards glare and visibility on wet roads, various combinations of symmetrical and non-symmetrical beam were used. When using only two 21-cp. incandescent lamps, we were impressed with the lack of light flux necessary to meet the requirements. With a limited light-output it is obvious that the light-distribution throughout the beam must be a compromise between the high-intensity driving-beam and the wide and lower-intensity portion desirable on curving roads and when turning corners.

One system which proved satisfactory was obtained through the use of three head-lamps. The two outer lamps were equipped with lenses having a 40-deg. spread and gave a relatively deep beam with an intensity of approximately 5000 candles. This beam was aimed so that the top met the road 100 ft. ahead of the car. The beam from the third head-lamp had a spread of about 6 deg. and was aimed with its top horizontal and pointed straight ahead of the car to provide a good high-speed driving-light. By a two-filament lamp properly adjusted this top beam could be depressed slightly and shifted to the right. This combination was less glaring and gave better lighting on the right side of the road than our standard system.

A number of other combinations were tried but unfortunately weather conditions did not permit recording test data or taking photographs, hence a complete report on this phase of the work cannot be made at this time.

Conclusions Deduced from the Tests

As a result of this investigation, supplemented by a considerable amount of driving on wet and dry roads, the following observations are made:

(1) Comparing wet and dry roads, the effect of the wet road-surface is to change the light-distribution materially, resulting in greater glare with its consequent interference with vision

(2) Meeting a given light-distribution, higher light-intensities are required to reveal an object on a wet road than on a dry road, due to greater interference with vision and also to change in light-distribution

(3) Increasing the light-intensity in a symmetrical system does not give greater revealing power

(4) The use of a non-symmetrical system in which the high-intensity portion of the beam is directed to the right of the car axis reduces glare and affords better vision

(5) Rigid adherence to the use of two 21-cp. lamps has resulted in insufficient light-flux being available to meet all requirements. It is believed that more light could be used to advantage in providing a distribution better suited to meet varying road and weather conditions

(6) The use of a very wide-spread low-intensity beam near the car, in conjunction with a relatively narrow controllable high-intensity driving-beam, seems to possess advantages for both dry and wet roads

(7) With reference to the low-intensity beam referred to in (6), which corresponds in aiming to the present depressed beam but has much lower intensity and wider spread, we know of no reason why fixed-focus design should not be used with a somewhat longer focal-length than the present standard and employing suitably designed reflectors or lenses

(8) The use of auxiliary driving-lights in which the beam is directed to the right of the car axis should be encouraged. In addition to affording better view of the right side of the road, this brightly lighted area tends to keep the driver's eyes directed away from oncoming lights, which is an advantage

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TRANSCONTINENTAL HIGHWAYS

During the last year, additions to the Federal-Aid system of highways totaled 9400 miles, bringing the aggregate Federal-Aid improved highways to 55,903 miles. Equally important extensions have been made to the State primary systems and, in particular, to the main East and West and North and South roads.

An outstanding route, because of its significance as a mid-continental connected highway from Atlantic City, N. J., to San Francisco, is United States Highway No. 40. This touches such important cities as Baltimore; Wheeling, W. Va.; Columbus, Ohio; Indianapolis; St. Louis; Kansas City, Mo.; Denver; Salt Lake City; and Reno, Nev. The entire length is 3220 miles and the route is paved throughout from Atlantic City to St. Marys, Kan., a distance of 1302 miles. West of St. Marys, the roadway is chiefly graded earth or gravel, except between Auburn, Cal., and San Francisco, where there is a continuous stretch of pavement. This route crosses the Great Salt Lake Desert over the famous Wendover cutoff.

Another route of importance is No. 30, which extends from Atlantic City, N. J., to Portland, Ore. It coincides with the Lincoln Highway between Philadelphia and Granger, Wyo. In passing through Pennsylvania the route touches also Lancaster, Gettysburg, Chambersburg and Pittsburgh, but passes through no large city in Ohio and bypasses Chicago through Chicago Heights and Joliet to Aurora, Ill. At Granger, Wyo., Route No. 30 divides into 30 North and 30 South, the southern branch going through Evanston, Wyo., to Ogden, Utah, while the northern division continues into Idaho through Montpelier and Soda Springs, Idaho. At Pocatello the route follows the Snake River somewhat closely, and in Nebraska, Idaho and Oregon it coincides with the old Oregon Trail. This route is improved with gravel, bituminous macadam, or smooth pavement as far as Wheatland, Iowa, and from Border, Wyo., to Portland, Ore., with varying stretches of gravel or pavement. Nearly 90 per cent is surfaced.

Route No. 20 will carry the motorist westward from Boston through Albany, N. Y., to Buffalo, and then over a highly improved Canadian road to Detroit. The tourist who seeks a route to follow still farther westward may take No. 10, through Saginaw to Ludington, Mich., where Lake Michigan is crossed by ferry to Manitowoc, Wis., and then touching Minneapolis; Fargo and Bismarck, N. D.; and Billings and Missoula, Mont., to Seattle. About three-fourths of this route is surfaced.—*American Motorist.*

Recent Developments in Aircraft Ignition-Systems

By F. G. SHOEMAKER[1]

CHICAGO SECTION PAPER *Illustrated with* DIAGRAMS AND PHOTOGRAPHS

ABSTRACT

THE fundamental electrical and mechanical requirements of ignition equipment for aircraft engines are outlined and the special requirements peculiar to this service and that apply, in general, equally to military and commercial aircraft, are described. Brief descriptions are given of various new types of both magneto and battery ignition and the developments in each are pointed out. Characteristics of an ideal ignition system are enumerated as a basis for further development. Among the general requirements reliability is given place of first importance, followed by light weight, compactness, low cost and adaptability of a single model to engines of different types. The chief design-requirements are speed, ruggedness, simple mounting, light rotating-parts, resistance to vibration, ample lubrication, protection against moisture, and fire-proof ventilation. Each of these subjects is dealt with specifically.

Difficulties of meeting the exacting electrical requirements are explained and means employed to overcome them are described. Too great spark energy may cause "overlapping," which, with battery ignition, results in burning of the breaker contacts, and, in magneto ignition, reduces the intensity of alternate sparks. For ignition of supercharged engines at high altitude where the air density is much reduced, the air insulation of the ignition system is much less effective than at sea-level, and a flash-over distance to ground of roughly 0.75 in. is required. Coil failures will result unless the length of the coil is increased to provide this gap or all the air-spaces are filled with some insulating material.

The principles of shielding the ignition system to prevent interference with radio communication are explained and complete shielding of the system for a Liberty-12 engine, as developed by the Signal Corps and Radio Unit at McCook Field, is shown. As a result of tests to determine fire hazards, the Experimental Engineering Section developed a type of magneto vent for ventilation and drainage which is shown.

Several types of two-spark or double magnetos for supplying sparks to two sets of spark-plugs are illustrated and described, as is also a pivotless type of high-speed breaker-mechanism developed by the Materiel Division at McCook Field. Several new battery-ignition distributors as developed for use on airplanes that carry equipment requiring a generator and battery are described, and the author lists the relative advantages of battery and magneto ignition. He then tells the requirements of an ideal airplane ignition-system, states those that have been met satisfactorily, but concludes with the statement that development of ignition equipment especially adapted to aircraft engines has only begun.

DURING the World War, a feverish attempt was made to adapt existing types of ignition equipment to the requirements of aircraft engines and new models were built by several manufacturers. In most cases, however, this development stopped abruptly at the end of the war and practically all development since then has been at the instigation of the Air Corps, with the cooperation of a few of the large manufacturers. This development was somewhat slow up to the beginning of 1926, as the limited market for new types did not seem to warrant any great activity on the part of the manufacturers. But the stock of surplus war-type engines has become smaller and the number of airplanes in service has increased until a rapidly increasing market for new ignition-equipment has caused at least one company to go into the manufacture of aircraft magnetos exclusively; and increased interest is being shown by other manufacturers.

Virtually all American aircraft-engines, with the exception of the Liberty-12, have been equipped with two single magnetos, most of which were supplied by the Scintilla Magneto Co., whose Type-AG magneto is regarded as the best single aircraft-magneto available in production quantities in this Country. The trend of development of all aircraft equipment is to reduce the size and weight and to increase the reliability and output; and this has been the object of the work on ignition done by the materiel division of the Air Corps.

The only recent discussion of ignition has been presented by Dr. F. B. Silsbee, of the Bureau of Standards, his paper[2] being devoted principally to the electrical behavior of the source of the sparks and the process of ignition. The object of this paper is to outline the fundamental electrical and mechanical requirements of ignition equipment for aircraft engines and to explain the special requirements peculiar to this service. In general, these requirements apply equally well to military and to commercial aircraft. The various new types of battery and magneto ignition are also described briefly and the developments in each are pointed out. The characteristics of an ideal ignition-system are outlined as a basis for further development.

GENERAL REQUIREMENTS

The general requirements of aircraft ignition are reliability, low weight, compactness, low cost and adaptability. Since the flight of an airplane depends upon the continuous operation of the powerplant, reliability is undoubtedly the most important requirement of ignition equipment. The increased use of aircraft for commercial purposes is making the factor of cost more and more important, but, in aircraft, cost can never be placed ahead of reliability. This is not always the case in automotive vehicles. Light weight is also an important factor, since the weight of the ignition equipment is parasitic, that is,

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[2] See THE JOURNAL, November, 1926, p. 442.

it does not add to the structural strength of the airplane. Compactness is important, for it usually means simplicity as well as reduction in weight. As a matter of production and maintenance cost, the question of adaptability of one model to different types of engine is of interest to the manufacturers both of ignition equipment and of engines.

Design Requirements

The chief requirements of mechanical design are speed, rugged construction, simple mounting, light rotating parts, resistance to vibration, ample lubrication, freedom from moisture, and fire-proof ventilation.

The first problem encountered in developing aircraft ignition-apparatus is that of operating continuously at high speed. A 12-cylinder aircraft-engine cruising at 1500 r.p.m. requires 9000 sparks per min., or 150 per sec. In pursuit planes, when diving at full throttle, the engine speed may easily reach 3000 r.p.m., requiring 18,000 sparks per min., or 300 per sec., whereas the normal speed for such engines is approximately 2000 r.p.m. There is good reason to believe that normal speeds of 3000 r.p.m. will be reached in a few years so that the requirements for high speed are still rising.

In engines weighing 2 lb. per hp. or less, the mass of the engine is small, compared with the inertia forces and torque reactions; consequently, vibrations of very high frequency are likely to be encountered. Such vibrations require only a short time in which to develop fatigue failures in parts such as mounting flanges, coil leads, condenser terminals, and the like, unless great care is taken to prevent repeated reversals of the stresses near the fatigue limit of the material. Experience has shown that ordinary automobile ignition-equipment is entirely unsuited to aircraft service on this account. The construction throughout must be of the most rugged type. Whenever possible, integral construction should be used, such as casting the body, pole-pieces and end frame of a magneto as a single unit. Studs with castellated nuts are preferable to screws and lock-washers for joining major parts. Apparently, every increase in engine speed produces a new list of vibration failures in equipment that had previously given no trouble whatever at the lower speeds.

As a result of the necessity for low weight, the crankshaft and the accessory drives are as small as possible and are therefore subject to rapid torsional vibrations. The twist of a 12-cylinder engine crankshaft at full throttle may exceed ± 2 deg. at each power-impulse. Because of such variations in angular velocity transmitted to the ignition drive, it is essential that the moment of inertia of the rotating parts be kept as low as possible, to reduce the size and weight of the drive required. In some cases, it is necessary to introduce a flexible coupling between the crankshaft and the magneto. This distortion is so serious with the Liberty-12 engine that an attempt to use magnetos was abandoned on account of drive failures. A multitude of flexible magneto couplings are available but few are free from trouble in service. Too much flexibility allows the spark-advance to wander about over a considerable range above and below the desired point. This may cause engine roughness, as the sparks that occur in the extreme-advance position cause those particular cylinders to detonate.

If the flexible coupling can be dispensed with, a simple flange-mounting, with a driving-spline or gear directly on the rotor shaft, can be adopted. This reduces the necessity for a heavy shelf or bracket that is required with the conventional base-mounting, and the direct drive eliminates the use of an intermediate driveshaft assembly. By slotting the holes for the magneto flange-bolts, a simple means is provided for the accurate adjustment of the timing.

It is a very difficult problem to assure ample lubrication of the bearings, cam and breaker-arm while preventing oil from creeping into the distributor or on to the contacts. Both magnetos and distributors, as ordinarily installed, run at a fairly high temperature and the oil creeps wherever possible. The presence of parts carrying high voltage causes corona discharges, which, through their action on the oxygen and moisture in the air, cause the oil or grease to form gummy deposits on the bearings and exposed surfaces, unless the apparatus is well ventilated and the oil-supply replenished.

The presence of moisture inside a magneto or distributor is objectionable on account of the leakage of electricity across the moist insulation, and the rusting of the metal parts and bearing-surfaces. The crankcase vapors are completely saturated with water vapor, which condenses as soon as it strikes a cool surface; and great care is necessary to prevent leakage of these vapors into the interior of the ignition system, particularly when a direct flange-mounting is used. Moisture may also form on the interior surface because of "breathing," or the passage of air into and out of the magneto as it cools off or becomes heated by the operation of the engine. To prevent this formation of moisture and to eliminate the corrosive gases, a certain amount of ventilation is required through properly located ventilating-holes. But these ventilating holes are themselves not entirely innocent of trouble. They must be properly shielded to prevent flames from being blown out through the vent holes in case a leakage of gasoline occurs and the sparks in the distributor ignite the vapors in the magneto, thus causing an explosion. This topic will be discussed in detail later.

Electrical Requirements

The electrical requirements for aircraft ignition-systems are considerably more exacting than those for other types of engine. The importance of engine reliability and the necessity for at least two spark-plugs in each cylinder, to assure rapid combustion without detonation, require two independent electrical sources of sparks. The high operating-speeds of the engine require the magnetic and the electrical circuits to be designed for high-frequency operation. At these frequencies, the hysteresis and eddy-current losses in magnetos may cause an undue temperature-rise in the coil and pole-pieces, unless the magnetic circuit is carefully laminated. Since many engines operate more smoothly when the two spark-plugs fire at slightly different degrees of advance, it is necessary to provide means for staggering the sparks. In some types of magneto, the eddy currents in the rotating parts and the high-frequency static discharges roughen the bearing-surfaces and seriously shorten the life of the bearings. This necessitates insulating the ball-bearing races.

It is generally thought that the greater the energy of the sparks, the better the ignition; and this is true for ordinary magneto or coil systems at moderate sparking-rates. Some slight trouble may result from rapid burning of the electrodes of the spark-plugs when the sparks are very "fat" and the electrodes operate at a high temperature; but this in itself is not a sufficient reason for limiting the spark energy. In high-speed multiple-cylinder engines, the interval between successive sparks is so short that the duration of the spark discharge must be considered. If the spark energy is too great and the secondary is not completely discharged when the primary

circuit is again closed, there is a residual voltage in the primary winding which affects the next succeeding spark.

This trouble is called overlapping and is the principal factor in limiting the spark energy of battery ignition-systems, for overlapping causes an excessive primary-current that rapidly burns the breaker contacts. In magnetos, because of the alternating polarity of the primary current, the effect of overlapping is to reduce the intensity of each alternate spark. Any excessive spark-energy over that required for satisfactory ignition is therefore undesirable, for it not only indicates excessive weight in unnecessarily large and heavy magnetic and electrical circuits, but may actually cause ignition trouble. Aircraft engines ordinarily do not start on the magneto directly; at cranking speeds, therefore, a hot spark is not required.

Sufficient experience has been obtained with air-gap distributors to demonstrate in many ways their superiority over the carbon-brush type. Tracking, due to carbon dust, moisture and oil, is practically eliminated and the necessity for special track-insulation and frequent inspection and cleaning has been eliminated. The loss of spark energy is not serious when the air-gap is small.

The usual method of obtaining ignition for starting, when magnetos are used, is to provide a hand-magneto with a starting-electrode in the distributor that trails the main electrode by from 30 to 60 deg. This gives the necessary retarding-effect by firing the cylinder that has passed top center. The weight of the starting-magneto must be charged to the magneto ignition.

Insulation for Supercharged Engines

One of the electrical requirements peculiar to ignition for aircraft engines is the ability to operate at high altitudes on supercharged engines. For military purposes, a great strategical advantage is secured in being able to fly at high altitudes. The density of the atmosphere above the earth decreases rapidly and, as a consequence, the power of the engine decreases in approximately the same proportion and limits the ceiling of the airplane. By using an air-compressor or supercharger, the air entering the engine is maintained at sea-level pressure and the engine power is kept at approximately its ground value, enabling the airplane to fly at much higher altitudes. Most present-day superchargers maintain sea-level air-pressure up to about 20,000 ft., where the air-density is approximately one-half that at the ground. It has been found that the dielectric strength of air varies roughly as the density, throughout the range encountered in flight, so that, at 20,000 ft., the air insulation of the ignition system is only one-half as effective as at the ground. The sparking voltage, however, is unchanged, as the air-density in the cylinders is the same as at sea-level. Laboratory tests show that a sparking voltage of at least 8000 volts is required, which is equivalent to the sparking voltage of a 0.2-in. (5-mm.) three-point air-gap at sea-level air-density. With insulating surfaces rather than air spaces, the flash-over distance required may be double that for air, or 0.4 in. Assuming a 20,000-ft. supercharger, it is seen that a flash-over distance to ground of roughly 0.75 in. is required. This requirement affects the design of the ignition at every point in the secondary circuit.

The secondary-coil windings are separated by layers of insulation, and the windings of each layer stop at from 1/8 to 5/16 in. from the ends of the coils, leaving air-spaces between the insulation at the ends of the coil. This air-insulation is reduced at high altitudes and coil failures will occur, unless the length of the coil is increased to give the required 3/4-in. air-insulation, or all the air-spaces are filled with some solid insulating-material. Obviously, the latter is the most desirable solution.

The safety-gap of most ignition systems is set at from 3/8 to 7/16 in. and flash-over will occur on a supercharged engine unless the safety-gap is increased, or some means is provided for keeping it at sea-level pressure, or independent of the air-density.

The next place for flash-over is from the distributor-rotor to the trailing-electrode for the starting-magneto, from one distributor segment to another, or to the ground. Flash-overs are particularly liable to occur inside the distributor, because of the ionized condition of the air owing to the constant sparking; and a generous flash-over distance is required. The secondary cable-terminals at both the distributor and the spark-plug are a source of trouble because of possibility of the effectiveness of the insulation being reduced by moisture or dirt. The proximity of carbureters, controls and cowling to the spark-plugs is also a source of trouble. At present, no magnetos are entirely satisfactory for use on supercharged engines. The Liberty Delco battery-ignition has proved to be satisfactory on account of its generous size and the inherently low voltage available from the secondary.

A method of maintaining the air insulation of the magneto by connecting its interior to the supercharger has been tried, but this adds complication to both the magneto and the engine and is only an expedient to allow the use of magnetos now available. The logical solution is the use of solid insulation that is not affected by amospheric pressure. This requirement is likely to change materially the detailed design of aircraft ignition-apparatus.

Radio Shielding

Radio communication is undoubtedly one of the most valuable and necessary aids to aviation that have been developed. It is a fortunate coincidence that radio has become available at about the same time that air transportation is being developed, for any extensive use of aircraft makes the use of radio communication imperative.

It is possible to obtain radio communication without ignition shielding by using a powerful sending-station and an insensitive receiver, but this requires large and heavy equipment and is limited in distance to the point at which the ignition noise drowns out the signal. By the use of shielded ignition, the power of the sending-station can be reduced, a more sensitive receiver can be used, and communication can be obtained over greater distances.

In order to understand the problem of shielding the ignition system to prevent radio interference, a simple case will be explained by means of the diagram in Fig. 1. Assume that the point a is a source of electrical radiation. As the potential of a varies, the electrostatic and electromagnetic fields about a vary in like manner. If a closed circuit, such as the ring b, is placed around a, a current will be induced in the ring by the varying field about the point a. This induced current in the ring b, in turn, sets up a field opposed to that of the point a. To neutralize the field of the point a in all directions, the closed circuit b must also lie in all directions; in other words, the point of radiation must be completely surrounded by a conducting-surface. If the neutralizing field is to be equal and opposite to that of a, the resistance of the paths b must be zero. Obviously, the resistance of these paths cannot be reduced to zero, so that absolute

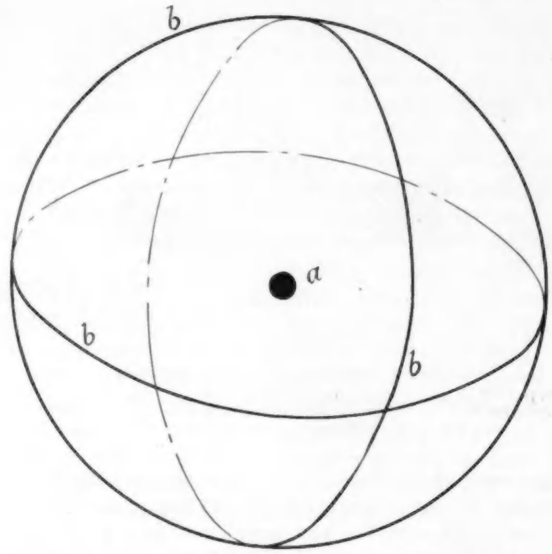

Fig. 1—Diagrammatic Illustration of Radio-Shielding Principle

As the Potential of a Source of Electrical Radiation, a, Varies, the Electrostatic and Electromagnetic Fields Surrounding It Vary Similarly. If a Closed Circuit, b, Is Placed around a, a Current Will Be Induced in b by the Varying Field around a. This Induced Current Establishes a Field Opposed to That of a, To Neutralize Which Completely in All Directions the Source of Radiation Must Be Completely Surrounded by a Conducting Surface That Offers No Resistance to the Flow of the Induced Current. Such Absolute Shielding Is Impossible, Owing to Imperfect Conductivity of the Shielding. As the Opposing Field Is Proportional to the Conductivity of the Surrounding Electrical Paths, Any Change in Resistance of These Paths, Caused by Intermittent or Sliding Contacts, Will Vary the Shielding Effect and Set Up Noises in the Radio Receiver

shielding is impossible, the results being in proportion to the conductivity of the shielding. This point is of the greatest importance in designing shielding, for there is a widespread notion that ignition shielding is similar to magnetic shielding, in that any sort of metallic housing around the ignition system will suffice. Since the opposing field is proportional to the conductivity of the surrounding electrical paths, it follows that any change in the resistance of these paths, such as may be caused by intermittent or sliding contacts, will cause the shielding effect to vary and to set up noises in the receiver.

In practice, it is necessary to surround the entire ignition system with well-bonded metallic housings that enclose the magneto, distributors, ignition cables, and as much of the spark-plugs as possible. The ignition-cable tubes must be grounded at each cylinder, as high-frequency static charges will build up on the tubes and arc across to neighboring conductors if the tubes are not grounded at least every 12 in. Fig. 2 shows the radio-shielding manifolds for the Liberty-12 engine and the method of shielding the spark-plug leads with copper braid over the cables that also serves to ground the manifolds. This shielding, developed by the Signal Corps and Radio Unit at McCook Field, is one of the most practical installations in use in this Country. On many engines, the use of radio shielding will necessitate a rearrangement of the accessories to allow the installing of the necessary manifolds and the proper housing of the distributor. The question naturally arises, why not use the cowling on all-metal ships as a means of shielding. This has been tried, but the necessity for bonding wires between the various sections of the cowling makes the inspection and care of the powerplant very tedious, and the shielding is only about one-half as effective as is the manifold type.

The effect of shielding on the ignition is of considerable importance also. The addition of grounded surfaces close to the secondary cables throughout their length increases their electrical capacity from 50 to 100 per cent. In some types of ignition in which the energy from the coil is limited, this increase in secondary capacity may be sufficient to prevent the coil from charging this capacity up to the required sparking-voltage, and missing will occur. When the spark energy is ample, however, the additional capacity causes the spark to be "snappier," by increasing the initial capacity-component of the spark. In one of the first shielded installations on the Liberty-12 engine, the secondary cables were each covered with a tightly woven copper-braid, and the entire bundle of wires was grounded to the engine at frequent intervals. This increased the secondary capacity to such an extent that missing occurred in service. By removing the copper braid from the cables and using metal covers over the distributors that were connected to the manifolds in the V of the engine, the capacity was greatly reduced and no further trouble was encountered. The following interesting examples illustrate some of the obscure sources of radio interference.

An engine was equipped with what was considered to be a satisfactory shielding manifold, but there was still considerable interference. Upon removing the equipment and substituting a set that had worked successfully on another engine, the spark-plugs were also accidentally changed to another type, and the interference disappeared. When the original manifolds were replaced, they worked satisfactorily, much to the surprise of those making the test. It was found that the original spark-plugs were of the auxiliary-gap type with a short spark-gap incorporated in the terminal nut. This gap acted as a small broadcasting-station that was not shielded by the copper braid on the cables. It has also been found that the primary-switch lead and the booster-magneto lead on a magneto will broadcast, unless properly shielded by a copper-braid covering. Incidentally, the entire wiring-system of the airplane, including the storage-battery and

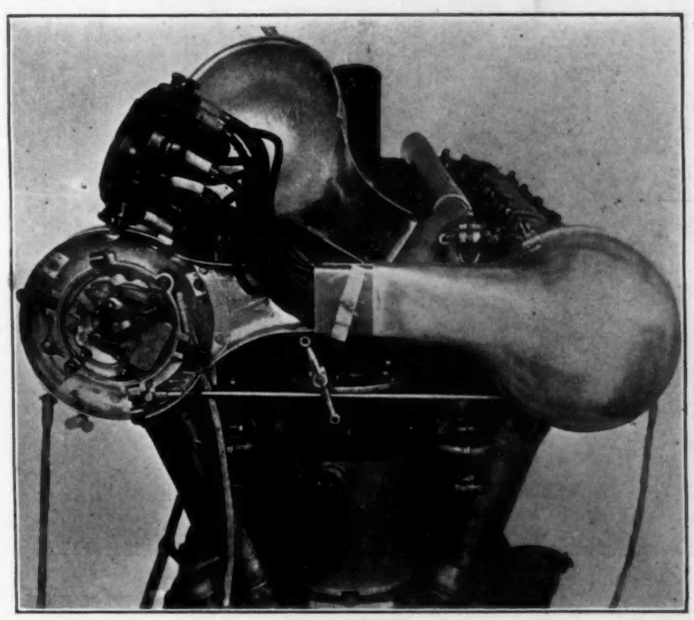

Fig. 2—Radio-Shielding Manifold on Liberty-12 Engine

This Shielding for Housing the Distributors and Cables and the Method of Shielding the Spark-Plug Leads with Copper Braid Were Developed by the Signal Corps and Radio Unit at McCook Field and Is One of the Most Practical Installations in Use in This Country. The Addition of Grounded Conducting Surfaces Close to the Secondary Cables throughout Their Length Increases Their Electrical Capacity from 50 to 100 Per Cent

the generator, must be shielded, and all brace wires must be carefully bonded together to prevent interference. This is particularly true with battery ignition, in which the primary-coil oscillations and the commutator ripple are fed back into the entire low-tension system. This may prove to be a point in favor of magneto ignition, for it may not be necessary to shield the lighting and the starting circuits, if no battery ignition is used.

In an ideal ignition system for radio-shielding, the secondary cables would be carried in passages integral with the cylinder-block or valve-housing, and the magneto or distributor would be completely enclosed in an integral metal-housing with a single-flanged opening leading to a corresponding opening in the cylinder-block. Such an installation would give inherent radio-shielding, protect the cables and magneto from oil, water and mechanical injury, and materially reduce the fire hazard.

Fire Hazard

A thorough investigation was recently undertaken by the Experimental Engineering Section of the Materiel Division to determine the cause and means of preventing fires in airplanes, both during flight and after accidents in landing. Obviously, if no gasoline, or other combustible substance, gets near the exhaust stacks, magnetos or other possible sources of ignition, no fires will occur; but so long as gasoline is piped to the carbureters, the engine is liable to be accidentally sprayed with gasoline or surrounded with gasoline vapors. This being the case, the possible sources of igniting these vapors should, so far as possible, be eliminated.

With this in mind, various types of magneto and distributor were tested to determine a suitable means of preventing them from starting a fire when they were sprayed with gasoline or surrounded with gasoline vapors. It has already been pointed out that some ventilation of the air-gap distributor is required, so that tightly closing the magneto is out of the question. In testing the magnetos and distributors for fire hazard, they were set up on a test-stand and driven by a motor, as shown in Fig. 3, and gasoline was sprayed over the entire magneto from a blow-torch. The fires that did occur were the result of a sharp explosion inside the magneto that blew flames out of the vent-holes and ignited the gasoline outside the magneto. However, it often required many trials before a fire could be started. It was a great surprise to find that a 40-mesh brass-screen over a ¼-in. vent-hole was entirely ineffective in stopping the flame.

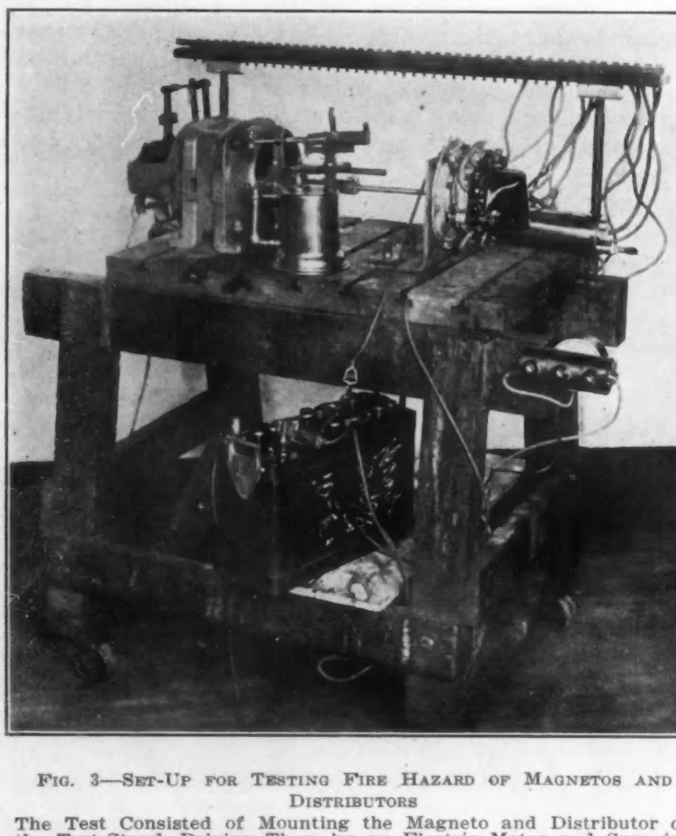

Fig. 3—Set-Up for Testing Fire Hazard of Magnetos and Distributors
The Test Consisted of Mounting the Magneto and Distributor on the Test-Stand, Driving Them by an Electric Motor and Spraying Gasoline All over the Magneto from a Blow-Torch. Many Trials Were Required before a Fire Could Be Caused. Such as Did Occur Resulted from a Sharp Explosion inside the Magneto That Blew Flames Out of the Vent-Holes. A 40-Mesh Brass-Screen over a ¼-in. Vent-Hole Did Not Stop the Flame. When Gasoline Is Sprayed over Any Ignition Apparatus, Enough Will Creep into the Interior To Cause a Combustible Mixture That Can Be Ignited

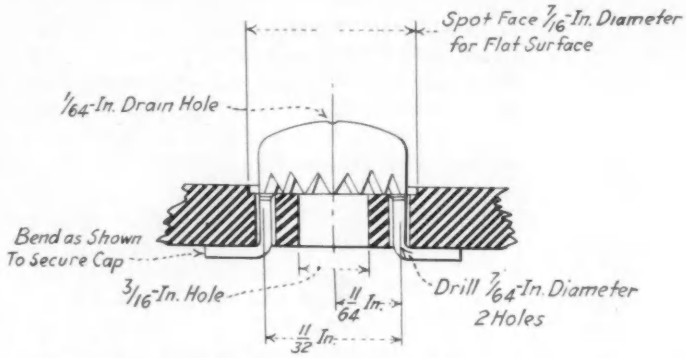

Fig. 4—Ventilating and Flame-Quenching Vent
This Type of Vent Was Developed To Provide Ventilation and Drainage and To Quench Flame from Internal Explosions by Cooling and Diffusing the Ignited Gases

After carefully considering these tests and conditions during flight, it was decided that when any ignition-apparatus is sprayed with gasoline, enough gasoline will creep into the interior to form a combustible mixture that can be ignited by either the sparks at the breaker-contacts or the sparks in the distributor. Since such explosions may occur, it is necessary to design the magneto and the necessary vents in such a manner that no flame will be blown outside the magneto. The type of vent shown in Fig. 4 was finally developed as a simple means of providing ventilation and drainage and, at the same time, of quenching the flame by cooling and diffusing the hot gases, in case of an internal explosion.

The present test-method consists of introducing gasoline into the interior of the magneto in the proper proportions to produce a sharp explosion when the ignition is switched on. All the spark leads are connected in the usual way to protected spark-gaps, and the entire magneto and wires are sprayed with aviation gasoline before the spark is turned on. At least 10 such internal explosions shall be obtained without resulting in a fire. This usually means at least 50 explosions of varying intensity. The magneto is then run continuously at normal speed for 30 min. and, at frequent intervals, gasoline is sprayed over the entire magneto. After each spraying, the gasoline is allowed to evaporate before the next spraying, thus going through all stages of vapor density in and about the magneto. If no fire results from these tests, the magneto is considered fire-proof.

Another possible source of fire is the loose connections between the spark-plug cables and the distributor, or the terminals of the plugs, which allow small sparks to occur as the cables vibrate. A safety-lock terminal has been developed that positively locks the terminal on the spark-plug and assures a tight contact, at the same time allowing the requisite flexibility. It is simple to operate and

requires no special tools for its operation, even in inaccessible locations in the V of the engine. The construction and method of attaching the terminal are shown in Fig. 5.

An inspection of several airplane engines run on the ground at night showed the presence of many coronas and static discharges from various metal parts around the secondary cables. These were particularly pronounced with magneto ignition. Under very favorable conditions, these static discharges will ignite gasoline. Several cases were found in which the ignition sparks themselves jumped to ground where the clearance was too small. The obvious remedy for such troubles is to enclose the secondary distributing-system completely with well-grounded metal manifolds and to provide sufficient insulation, or clearance, around the spark-plug terminals. This also meets the requirements of radio shielding, as previously outlined. In general, the problems of eliminating fire hazards due to the ignition-system are mostly mechanical and have little or no effect on the electrical design of the ignition-system.

The general requirements outlined above are the features that are desired in aircraft ignition-equipment, but, unfortunately, all these problems have not been solved up to the present time. Some progress has been made, however, in obtaining a reduction in weight and an increase in the satisfactory operating-speed of magneto ignition by the adoption of the double magneto and improvements in the design of the breaker mechanism.

Double Magneto

The idea of two-spark magnetos is not at all new, as magnetos with both ends of the secondary winding brought out through two distributors to two sets of spark-plugs were used many years ago. In fact, the first so-called "vertical double-magneto" submitted to the Air Corps was of this general type.

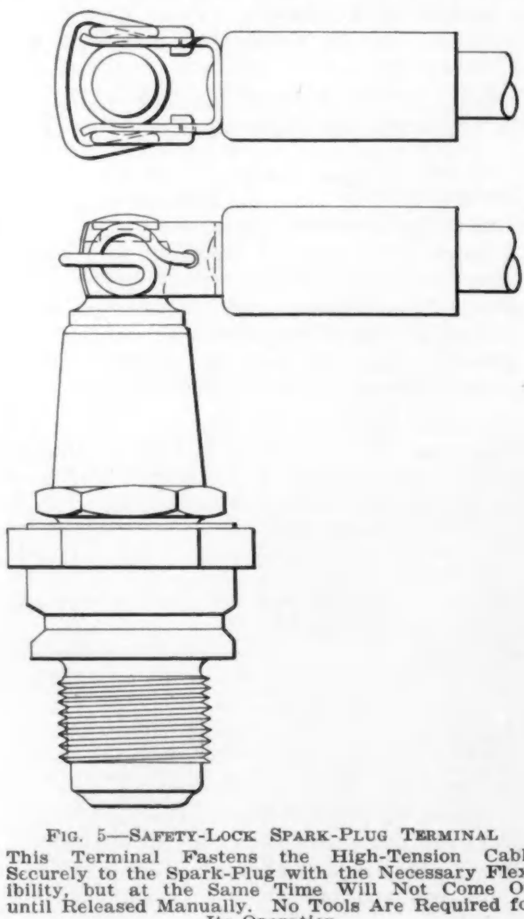

Fig. 5—Safety-Lock Spark-Plug Terminal
This Terminal Fastens the High-Tension Cable Securely to the Spark-Plug with the Necessary Flexibility, but at the Same Time Will Not Come Off until Released Manually. No Tools Are Required for Its Operation

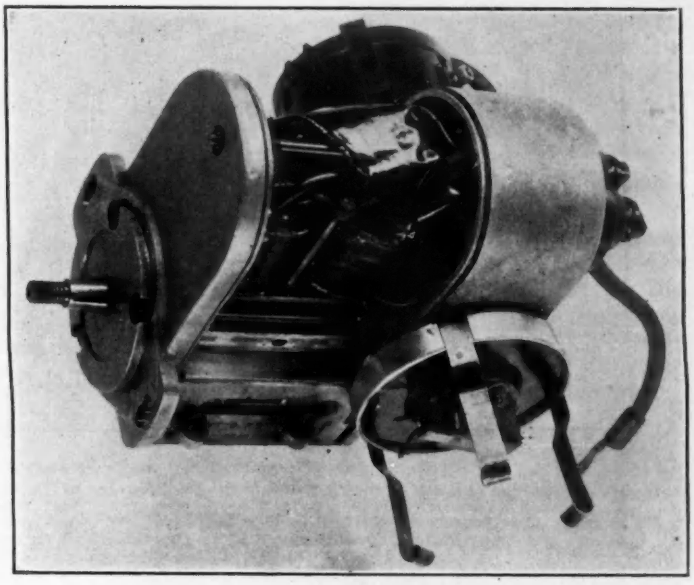

Fig. 6—Splitdorf Model-PA Vertical Double Magneto
This Produces Two Sets of Sparks from a Single Unit and Has a Flange for Mounting the Magneto in a Vertical Position at the Rear of the Engine for Driving from the Upper End of the Accessory Drive-Shaft. It Is Not Strictly a Double Magneto, as the Two Sets of Sparks Are Not Entirely Independent, but Its Construction Reduces the Weight of the Ignition System. The Two Sparks Are Obtained by Using Two Separate High-Tension Coils on One Magnetic Circuit

In an attempt to reduce the weight of the ignition system by eliminating the use of special mounting-brackets and drive-shaft assemblies, the Splitdorf Model PA vertical double-magneto was developed. The novel features of this type are the production of two sparks from a single unit and the flange mounting for driving the magneto in a vertical position at the upper end of the accessory drive-shaft at the rear of the engine. The magneto itself, as shown in Fig. 6, is a modification of the conventional Splitdorf SS model by the use of two separate high-tension coil-windings on one magnetic circuit, two breaker-levers, a mounting-flange on one end-plate, and two integral distributors. This is not strictly a double magneto, as the two sparks are not entirely independent of each other; but it furnishes sparks to two sets of spark-plugs and thereby reduces the weight of the ignition system, which was the primary object of the development. A complete analysis of the electrical characteristics of this magneto is beyond the scope of this paper, but a brief explanation will be given to explain the troubles encountered.

As pointed out above, two sparks are obtained by using two separate high-tension coils on one magnetic circuit. One end of each primary is connected to ground through a breaker mechanism, the two breakers operating simultaneously. The other ends of the primary windings are carried out to the ignition switch and are either connected together or grounded through the switch, thus requiring the primary current to flow through the switch in the running position. To run on one spark, the primary of the inactive coils is open-circuited and the active coil is connected to ground through an impedance-coil, to prevent an excessive primary-current at normal operating-speeds. Unfortunately, this also reduces the spark energy when running on one spark at low speeds. It was found in service that the short-circuiting effect of one fouled spark-plug would cause the other plug in the same cylinder to miss and foul-up. It was also found that

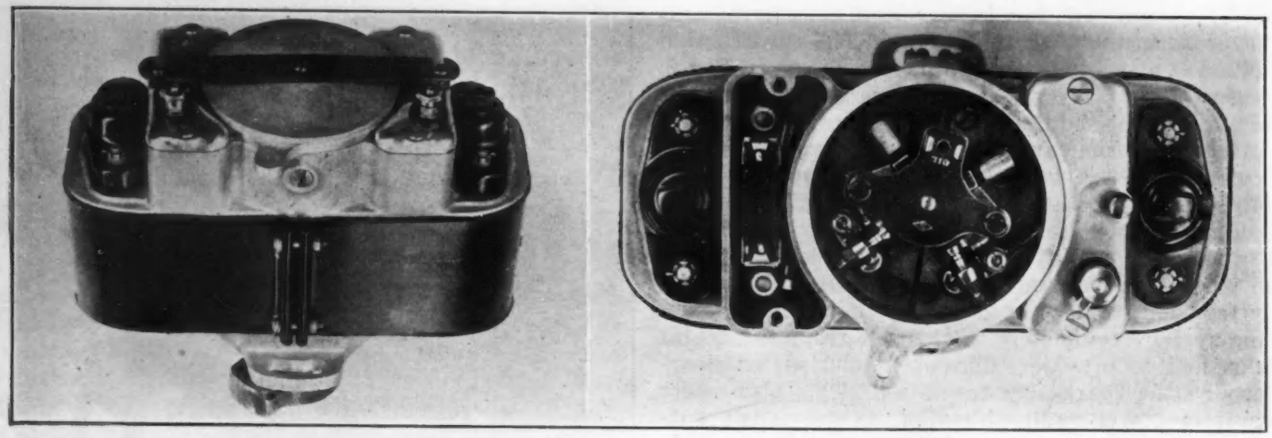

FIG. 7—SPLITDORF MODEL-VA DOUBLE MAGNETO DESIGNED ESPECIALLY FOR AIRCRAFT ENGINES
This Provides Two Electrically Independent Sources of Spark from One Unit That Weighs Less Than a Conventional Single Magneto. Has a Single Shaft with Flange Mounting That Allows Direct Gear or Splined-Shaft Drive: Preserves Constant Angular Relation between the Two Sets of Sparks, whether Synchronized or Staggered, with One Spark-Advance Control-Rod; Allows the Distributors To Be Driven from the Camshaft without Special Gear-Reduction; and This Single Type of Magneto Can Be Used for Engines Having Any Number of Cylinders

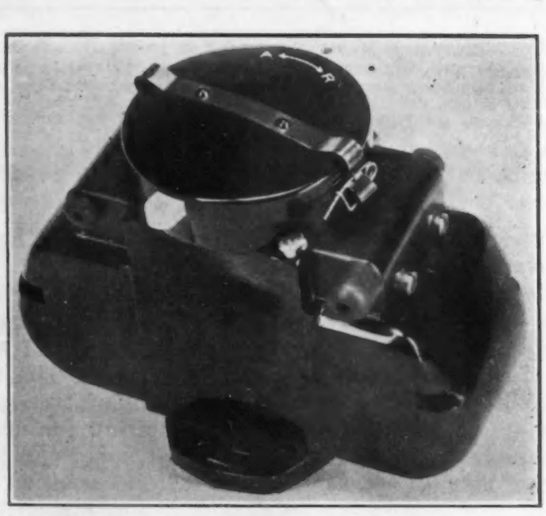

FIG. 8—SCINTILLA MODEL-SC DOUBLE MAGNETO
Some Distinctive Features of This Are a Weight of 12.50 Lb., a Cobalt-Steel Four-Pole Rotating Magnet Weighing 3.62 Lb., a Condenser That Is an Integral Part of the High-Tension Coil-Assembly between the Primary and Secondary Windings, Sliding Metal Brush-Connections, Very Low Hysteresis and Eddy-Current Losses, Bearings Supported in Insulated Cages, and Easily Removable Breaker

sparks could be obtained from either one or both the secondary windings when either one or both the primary circuits were interrupted, the spark apparently following the path of the lowest resistance. These troubles and the unsatisfactory performance of the breaker caused the abandonment of this type, but the attempt was very much worthwhile, as it showed the inherent advantages of the double-vertical type of magneto and led to the development of a true double-magneto.

At the request of the Materiel Division, the Splitdorf Electrical Co., through its chief engineer, E. B. Nowosielski, developed the Splitdorf Model-VA vertical double-magneto, as shown in Fig. 7. It is interesting to note that the first experimental model was made by splitting two Dixie-100 hand-starting magnetos horizontally through the center line and bolting the two halves together with a common inductor-rotor. This type of magneto is of a very simple, compact and rugged design and is probably the first type specially designed for aircraft engines. Following are the important features of the double type:

(1) Two electrically independent sources of spark from one unit weighing less than one conventional single-magneto
(2) Single shaft with flange-mounting allowing direct splined shaft or gear-drive and eliminating the necessity for special drive-shafts and mounting-brackets
(3) Constant angular relation between two sparks either synchronized or staggered; one spark-advance control-rod
(4) Distributors driven from the camshaft without special gear-reduction
(5) A single type of magneto for engines having any number of cylinders
(6) Rugged, compact, waterproof, and fireproof construction

The Splitdorf Model-VA vertical double-magneto, shown in Fig. 7, has the following distinctive characteristics:

(1) Weight, 15.5 lb.
(2) Two sets of magnets
(3) A single inductor-rotor, weighing only 1.5 lb. and having a very low moment of inertia
(4) Breaker mechanism and condensers accessible from the top of the magneto
(5) Breakers synchronized by shifting the split breaker mounting-plate about the cam

The Scintilla Magneto Co. has recently developed a double magneto known as the Model SC, having the same general characteristics as the Splitdorf Model-VA. The following are the distinctive features of this model, which is shown in Figs. 8 and 9:

(1) Weight, 12.5 lb.
(2) Four-pole rotating magnet of cobalt steel, weighing 3.62 lb.
(3) Condenser, an integral part of the high-tension coil-assembly lying between the primary and the secondary windings
(4) All primary and secondary conductors molded into a single terminal-block for each coil
(5) Sliding metal brush-connections to the breakers instead of stranded pig-tail connections
(6) Very low hysteresis and eddy-current losses
(7) One double-row self-aligning bearing on the driving end and one annular bearing on the cam end

(8) Both bearings supported in insulated cages
(9) Breaker assembly, or individual breakers, easily removable

The first Splitdorf Model-VA magneto, as well as its predecessor, the Model-PA, and the first experimental Scintilla Model-SB double-magneto, all gave trouble because of the short life of the breaker-mechanism. All three of these breakers were of the lever type with quick-lift cams, resulting in rapid contact-wear. It was apparent from the continued trouble with lever-type breakers on all makes of magnetos, when run at high speed, that any marked improvement in the life of the magneto would require a much better breaker-mechanism than any so far produced. The fact that practically all lever-type breakers use a bumper, or buffer spring, is sufficient evidence to show that these breakers are all operating above their safe speed. As a result of this situation, the Materiel Division undertook the development of a breaker that would overcome the difficulties encountered with the lever type.

High-Speed Breaker-Mechanism

The conventional lever-type breaker-mechanism of good design is satisfactory at sparking rates up to about 10,000 sparks per min. Above this speed, the inertia of the breaker lever is usually sufficient to prevent it from following the movement of the cam, and chattering occurs. Rather than overcome this chattering by increasing the spring tension on the lever, with the resulting increased contact and rubbing-block pressures, a solid bumper, or a buffer-spring, is placed behind the lever to limit its travel and to allow the spring to return the lever to the closed position in time for another spark. This chattering greatly increases the wear of the contacts by introducing high impact-loads as the contacts close, and by causing additional arcing at the contacts when the lever bounces several times before coming to rest. So long as the lever follows the cam, the closing velocity is governed by the contour of the cam and can be made much less than is the case when chattering occurs.

A cylindrical pivot-bearing is usually provided for the contact-lever, either near the center or at one end. This bearing must have an insulating-bushing in the lever to prevent the pitting of the pivot-pin by electrical discharges from the lever to the pin. These are usually high-frequency static discharges that occur in spite of the fact that the lever is grounded through the spring. The lubrication of this bearing is particularly difficult, as the motion is oscillatory, and foreign particles do not work out of the bearing; consequently, any rust, moisture or wear tends to cause the lever to stick. Some means for lubricating the pivot-bearing and cam must always be provided.

In practically all breaker-mechanisms, the contact separation is adjusted by mounting one of the contacts on a screw. After a short period of operation, the contacts form irregular surfaces that match perfectly so long as the moving contact returns to the same closed position. But, if the separation must be corrected, due to wear of the cam, rubbing-block, pivot-bearing, or the contacts themselves, the contact mounted on the screw must be rotated, and the matched surfaces no longer register accurately. Unless the surfaces are again care-

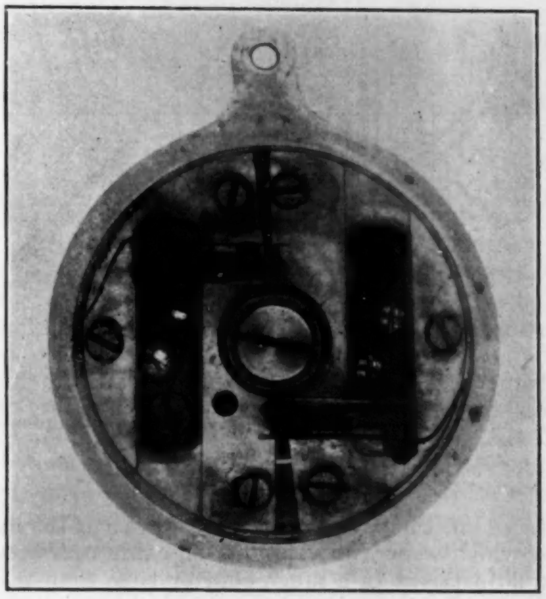

Fig. 10—Pivotless Contact-Breaker Developed by Materiel Division of the Air Corps

The Moving Contact Is Attached to the Spring That Returns the Contact to Closed Position, Thus Eliminating the Need for a Pivot-Bearing and a Breaker-Lever and Reducing to the Minimum the Moment of Inertia of the Moving Parts To Meet the Requirements of High-Speed Operation. Virtually the Entire Mass of the Moving Contact-Support Is Employed Usefully. A Lifter-Spring Holds the Rubbing-Block against the Cam and Relieves the Contact Element of Impact and Spring Loads. As Both Contacts Are Mounted Integrally on One Support in a Permanent Assembly, the Contact Separation Can Be Adjusted or the Breaker Synchronized by Moving the Whole Assembly in Relation to the Cam, without Disturbing the Contacts

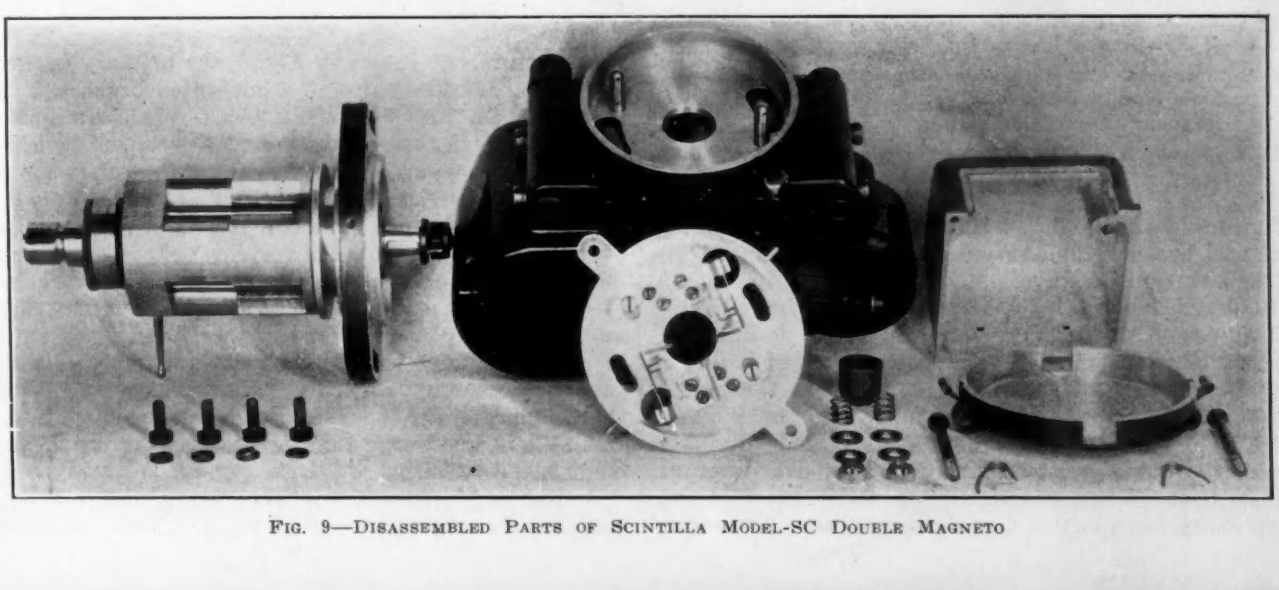

Fig. 9—Disassembled Parts of Scintilla Model-SC Double Magneto

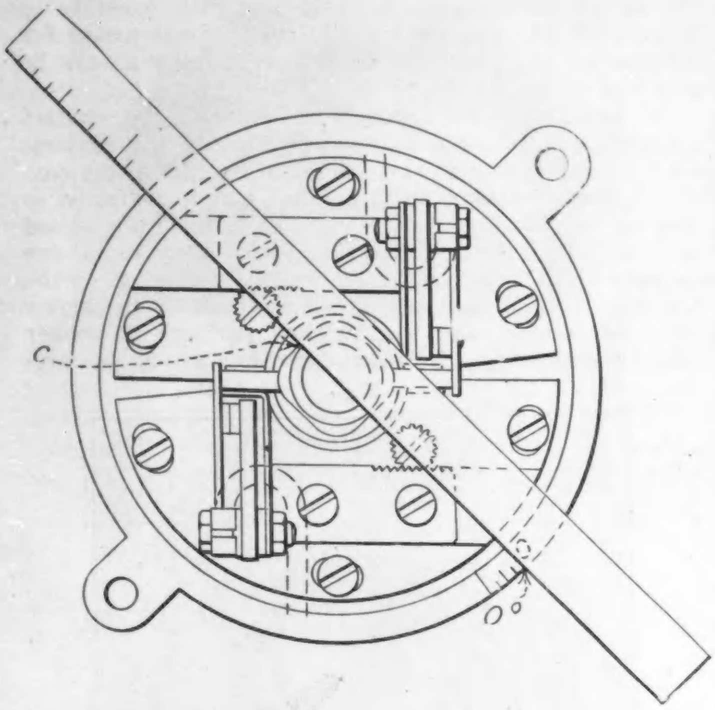

FIG. 11—METHOD OF "TIMING" CONTACT SEPARATION IN PIVOTLESS BREAKER

A Straight-Edge Is Laid across the End of the Cam against the Raised Shoulder *c* and the Rotor Is Turned until the 0-Deg. Mark on the Breaker-Housing Lines Up with the Straight-Edge, Indicating Full-Advance Position. Then the Two Clamping-Screws Are Loosened and the Contact Assembly Moved until the Contacts Separate

fully faced off, the points touch only on two of the highest points, which wear away rapidly, and this necessitates a second adjustment in a much shorter time than the first period. Experience shows that such breakers require frequent attention when operated on high-speed engines.

In an attempt to eliminate the various troubles encountered in service with the lever-type breaker, the experimental engineering section of the Materiel Division undertook the development of a breaker to meet the following requirements:

(1) Ability to operate continuously at speeds equivalent to 3000 r.p.m. on a 12-cylinder engine, at 18,000 sparks per min.
(2) Minimum impact-loads on the rubbing-block and contacts
(3) Elimination of the pivot-bearing and lubrication of the breaker-mechanism
(4) Simple adjustment of the breaker without special tools and without disturbing the alignment or refacing the contacts
(5) Elimination of flexible lead-wires from the primary winding to the breaker

After the design and construction of a number of experimental breakers and several thousand hours of testing, the two types of pivotless breaker shown in Figs. 9 and 10 were developed. To meet the requirement of high-speed operation, it was necessary to reduce the moment of inertia of the moving parts to the minimum. Since a spring is required to return the contacts to the closed position, the obvious method of mounting the moving contact is to attach it to the spring itself and eliminate the necessity for a pivot-bearing and a breaker-lever at the same time. Thus, practically the entire mass of the moving contact-support is usefully employed. Some sort of rubbing-block is required to operate against the cam, and, to eliminate the impact and spring loads on the contacts, if this rubbing-block were carried with the moving contact-spring, the lifter-spring is introduced. This is given sufficient tension to cause the rubbing-block to follow the cam and relieve the contacts of any unnecessary spring-pressure. It has been found that the spring-tension of both the contact-spring and the lifter-spring can be varied over a wide range without materially affecting the operation of the breaker, as the natural periods of both springs are well above any required operating-speeds. The contact pressure in itself does not materially affect the contact wear, if the impact loads are small.

One of the most important features of the design is the method of adjusting the contact separation without disturbing the relation of the contact surfaces. By mounting both contacts integrally on one support in a permanent assembly, the contact separation can be adjusted, or the breakers synchronized, by moving the whole assembly in relation to the cam without in any way disturbing the contacts. This makes it unnecessary for the contacts to be faced off or aligned after each adjustment, as they always fit perfectly even when badly pitted. Roughness itself is not detrimental so long as the contacts always meet in exactly the same way. The only tools required to adjust the contacts are a screw-driver and a feeler gage.

But the primary object of adjusting the contact separation is not to obtain a given lift on the breaker, but to interrupt the primary circuit when the rotor is in a certain relation to the pole-pieces. If nothing in the breaker has worn, except the contacts, and all the parts have been properly made and assembled, a specified contact-separation will cause the circuit to be interrupted, with the rotor in the desired position. But, after a time in service, the wear on the rubbing-block and the cam may allow this position to shift, even though the contact separation is maintained at the specified amount. The effect of breaker wear is more pronounced with the slow-lift cams required for high-speed magnetos. To assure the correct timing of the break under all conditions, the breaker shown in Fig. 9 was designed to be "timed" rather than adjusted for a given lift. As shown by the sketch in Fig. 11, a scale or straight-edge is laid across the end of the cam against the raised shoulder *c* and the rotor is turned until the scale lines up with the 0-deg. mark on the breaker-housing, when in the full-advance position. This gives the proper location of the rotor with respect to the pole-pieces. It is then necessary only to loosen the two clamping-screws and to move the contact assembly until the contacts separate. The only tools required are a scale and a screw-driver.

In the breaker shown in Fig. 9, the primary connection to the coil is made through a laminated brush that bears on a segment in the terminal block. This eliminates all flexible leads in the breaker and allows the entire breaker-assembly to be easily removed by taking off two nuts in the breaker housing.

The pivotless type of breaker has shown its superiority over the lever type from the very first experimental model. Three conventional lever types of magneto were bench-tested at 3800 r.p.m. and ran continuously without adjustment for 15, 100 and 116 hr. respectively. In each case, the contacts were worn sufficiently to require either refacing or renewal. The first pivotless type ran for more than 500 hr. on the same set of contacts at 4200 r.p.m. and was still in good condition, the total wear on the points being about 0.008 in.

A pair of pivotless breakers on a vertical double-magneto recently ran for 1015 hr. at 4200 r.p.m. without

any adjustment whatever and were apparently good for at least 500 hr. more before an adjustment would be necessary to correct the timing. At the end of this test, the magneto was run up to 8000 r.p.m. without misfiring or any chattering of the contacts. Development of the details of this type of breaker is still under way but the fundamental principles have already been established as entirely satisfactory.

All the Splitdorf double-magnetos have been equipped with tungsten contacts and their operation has been entirely satisfactory. The principal difficulty previously experienced with tungsten contacts has been hard starting, because of a high-resistance coating that forms on the contacts if they happen to stand apart for several days. This apparently causes no trouble on the double magnetos, as the contacts are "made" several times while the booster magneto is furnishing the ignition during starting, and this breaks down any surface resistance. The use of tungsten contacts greatly reduces the cost of the magneto.

Battery Ignition Development

As a matter of fact, comparatively little development in battery ignition for aircraft engines has taken place since the war. Under the pressure of wartime demands, the Liberty-12 Delco ignition-distributor was developed in a very short time, and practically the entire supply was produced without any changes in design. It is a tribute to the manufacturer that this type of distributor has given good service ever since. It is only within the last 2 years that any new types have been designed, chiefly on account of a different angle between the cylinders and of higher engine-speeds.

The Liberty Delco distributor assembly is shown in Fig. 12 and is characterized by the following features:

(1) Direct drive from the camshaft
(2) Ignition-coil integral with the distributor-head
(3) Double breaker-arms
(4) Auxiliary contact-arm to prevent sparking on reverse rotation
(5) Carbon-brush-type distributor
(6) Spark-advance effected by shifting the entire distributor

The use of a carbon brush in the distributor necessitates frequent cleaning of the distributor track to remove the oil and carbon. It has also been found that moisture in the coil insulation that had not been entirely removed during the process of manufacture greatly reduces the energy of the spark, when the coil reaches a temperature of more than 150 deg. fahr., sometimes causing scattered missing and roughness of the engine. This has been a very obscure trouble and, as usual, the condenser has been blamed for much of it. The usual method of cure has been to put on a new distributor. More or less trouble has always been caused by oil leakage, particularly on inverted engines. To overcome this trouble and to improve the reliability of the distributor, the Materiel Division, with the cooperation of the Delco Co., has worked out the following modifications, for converting the carbon-brush type of distributor into what is called the Liberty Delco air-gap type of distributor:

(1) Carbon brush replaced with metal pin to give an air-gap distributor
(2) All moisture removed from coils by careful

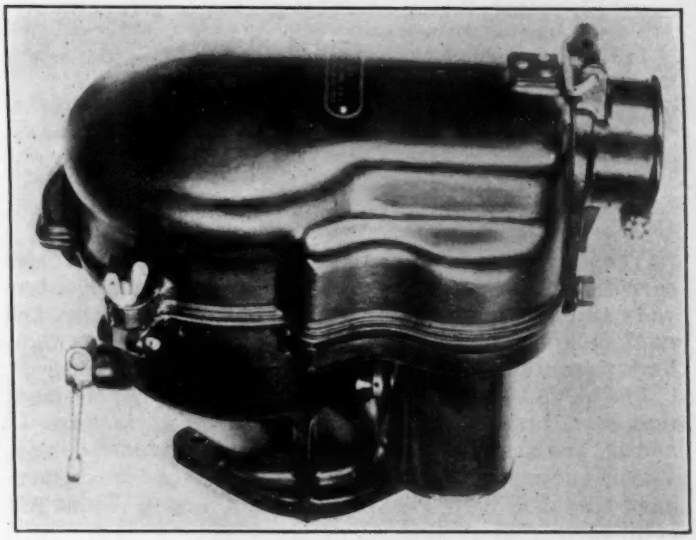

Fig. 13—Delco Ignition-Distributor for Nine-Cylinder Radial Aircraft-Engine

This Is an Emergency Magneto-Replacement Unit and Is Not To Be Continued. All Parts Are Enclosed for Radio Shielding

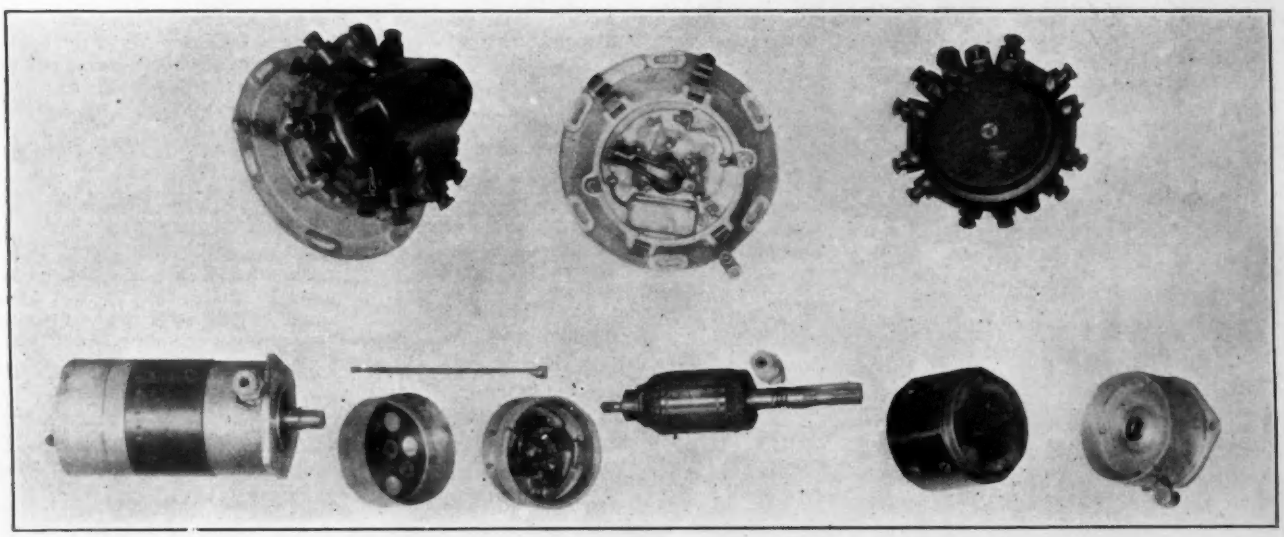

Fig. 12—Liberty-12 Delco Ignition-Distributor Assembly Components

This Distributor Has Direct Drive from the Camshaft, an Ignition-Coil Integral with the Distributor-Head, Double Breaker-Arms, an Auxiliary Contact-Arm To Prevent Sparking on Reverse Rotation, a Distributor of the Carbon-Brush Type, and the Entire Distributor Is Shifted To Effect Spark Advance

vacuum-drying at 250 deg. fahr, and revarnishing the exterior

(3) Upper rotor-shaft bearing replaced with new bearing having integral oil-retaining washer
(4) Bakelite coil-housing and aluminum distributor-cup replaced with new parts accurately machined to assure concentric distributor track
(5) Suitable oil-drain holes provided to remove the excess oil
(6) Fire-proof vent-holes in distributor cup

These changes have virtually eliminated troubles from carbon on the track and oil leakage. Four distributors were run on the bench for 350 hr. without attention and no "tracking" was experienced. Service tests in flight have shown a similar freedom from carbon troubles.

The only new designs have been a magneto-replacement unit for a nine-cylinder radial engine, shown in Figs. 13 and 14, and an ignition distributor for 12-cylinder 60-deg. V-type engines, shown in Fig. 15. The magneto-replacement unit has two breakers, two coils and a double 18-point air-gap distributor. The spark-advance is adjusted by advancing the cam through a spiral slot in the driving-shaft. The entire unit is enclosed for radio shie'ding. Although somewhat bulky, on account of using the standard parts available at the time, the unit has given practically no trouble. This was an emergency magneto-replacement unit and will not be continued.

The 12-cylinder 60-deg. V-type distributor, shown in Fig. 15, was developed to meet the requirement for a light compact high-speed battery-ignition system for engines in airplanes that carry other electrical equipment requiring a generator and battery. The particular type shown was designed for driving from the camshaft drive-shaft-housings on the Packard 1500 and 2500 engines. Following are the principal design features:

(1) Twelve-lobe cam with double breakers
(2) Air-gap distributor
(3) Separate ignition-coils

This type of distributor has given satisfactory service and can be adapted to different engines without difficulty.

Battery versus Magneto Ignition

The old controversy between battery and magneto ignition is no nearer a solution than ever; in fact, it is like Lincoln's silk hats: "They mutually excel each other." The following brief statements outline the situation as regards their application to aircraft engines, no attempt being made to draw conclusions:

(1) No evidence indicates that the spark-plugs know where the sparks come from; therefore, one good spark is equal to another good spark
(2) Thousands of engines are operating satisfactorily on magneto and on battery ignition-systems
(3) When electrical equipment is required for radio or lights, the battery ignition-system should not be charged with any of the battery or generator weight, as this cannot be reduced by using magnetos. Therefore battery ignition is lighter than magneto ignition as now available
(4) When radio shielding is required, the additional shielding of the generator and of the lighting circuits, required with battery ignition, may offset the additional weight of magneto ignition
(5) The sparking rates of high-speed multiple-cylinder engines are approaching the limits obtainable from one present-type battery ignition-coil operating at from 12 to 15 volts. The speed limitations of magneto ignition are principally mechanical and are not likely to be reached soon
(6) Battery ignition does not require a hand-starting magneto
(7) The sparking ability of a magneto is not dependent on a battery and therefore is not affected by long periods of storage or idleness
(8) A battery ignition-system is cheaper than a magneto system

This list can be added to indefinitely, but the above considerations are enough to show that the choice between battery and magneto ignition depends almost entirely on factors aside from that of spark intensity, which is the usual subject of controversy.

The fo lowing tabulation gives the weights of several battery and magneto ignition-systems on different types of engine. In some cases the weights of both battery and magneto systems are given for the same engine, thus affording direct comparison.

For those who insist that battery ignition be charged with a part of the generator and battery weight in proportion to the ratio of the average ignition current to

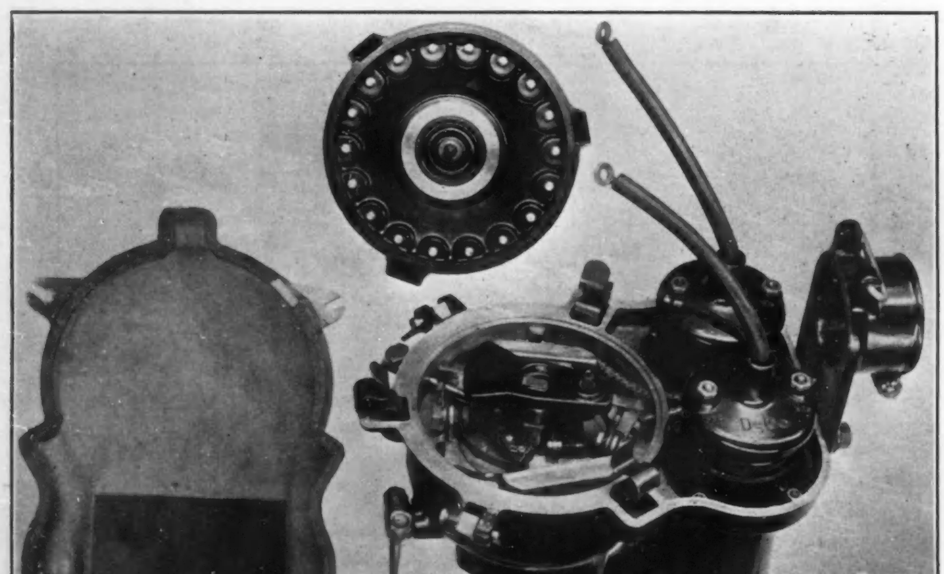

Fig. 14—Delco Distributor with Shield Removed

The Assembly Includes Two Coils, Two Contact-Breakers and a Double 18-Point Air-Gap Distributor. The Spark-Advance Is Adjusted by Advancing the Cam through a Spiral Slot in the Driving-Shaft

the generator capacity, it may be pointed out that, for the largest generator now in service, which has 50-amp.

WEIGHT OF IGNITION SYSTEM

Liberty-Delco 8-Volt System for Liberty-12 Engine

	Lb.
2 Ignition-Distributors	10.5
1 8-Volt Battery	11.0
1 Switch and Voltage-Regulator	2.1
1 8-Volt Generator	11.5
Total	35.1

Dixie 800 Magneto for Wright E Engine

2 Dixie-800 Magnetos	33.6
2 Drive Assemblies and Mounting-Bracket[3]	12.0
1 Starting-Magneto	8.1
1 Switch	1.2
Total	54.9

Delco Ignition-Distributor on Curtiss R-1454 Radial Air-Cooled Engine

1 Ignition-Distributor Assembly	13.4
1 Switch[4]	1.0
Total	14.4

Splitdorf-PA Double Magneto on Curtiss R-1454 Radial Air-Cooled Engine

1 Splitdorf-PA Double-Magneto	18.5
1 Dixie-100 Starting-Magneto	8.1
1 Switch	1.2
Total	27.8

Delco Ignition-Distributor on Curtiss D-12 Engine

2 Delco Ignition-Distributor Assemblies	10.0
2 Distributor-Drive Assemblies and Adapters	5.5
2 High-Tension Coils	4.4
1 Switch[4]	1.2
Total	21.1

Splitdorf SS-12 Magneto on Curtiss D-12 Engine

2 Splitdorf SS-12 Magneto	28.2
2 Coupling and Drive Assemblies	3.0
2 Mounting-Brackets[3]	2.5
1 Switch	1.2
1 Starting-Magneto	8.1
Total	43.0

Splitdorf VA-1 Double-Magneto on Curtiss D-12 Engine

1 Splitdorf VA-1 Magneto	15.5
1 Magneto Adapter-Flange and Drive-Coupling	1.9
2 Distributor-Drive Assemblies	4.5
2 Distributor-Heads and Rotors	3.0
1 Switch	1.2
1 Starting-Magneto	8.1
Total	34.2

Delco Ignition-Distributor for Packard 1500 and 2500 Engines

2 Ignition-Distributors	10.0
2 High-Tension Coils, Type D	4.4
1 Switch	1.0
Total	15.4

Scintilla AG 12-D Single Magnetos on Packard 1500 Engine

2 Scintilla-AG 12-D Single-Magnetos	29.8
2 Coupling and Drive Assemblies	3.0
1 Mounting-Bracket[3]	12.0
1 Switch	1.2
1 Starting-Magneto	8.1
Total	54.1

[3] Estimated.
[4] Not including generator or battery weight.

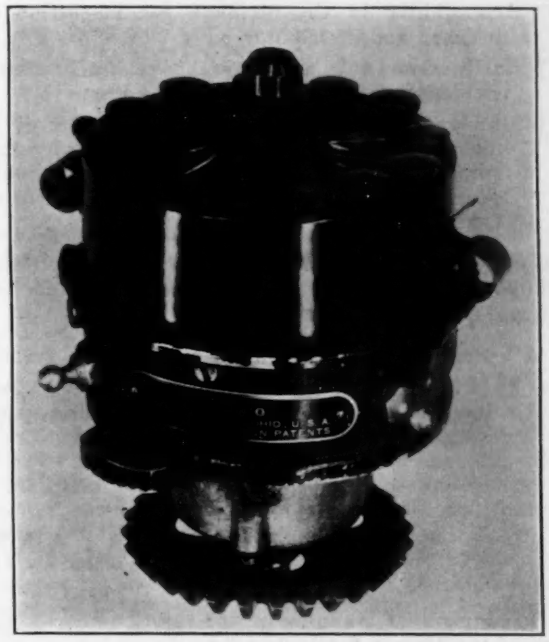

FIG. 15—DISTRIBUTOR FOR 12-CYLINDER 60-DEG. V-TYPE ENGINES
This Was Developed To Meet the Requirement for a Light Compact High-Speed Battery-Ignition System for Airplanes That Carry Other Equipment Requiring a Generator and Battery. It Was Designed for Driving from the Camshaft Drive-Shaft-Housing on the Packard 1500 and 2500 Engines but Can Be Adapted to Different Engines without Difficulty. The Principal Design Features Are a 12-Lobe Cam with Double Breakers, an Air-Gap Distributor and Separate Ignition-Coils

capacity, this burden amounts to only slightly more than the weight of a starting magneto.

From the foregoing tabulation, it is seen that battery ignition, exclusive of generator and battery, weighs less than one-half that of the equivalent magneto-ignition, when two single magnetos are used, and not more than two-thirds as much, when a double magneto is considered. With an ignition battery and generator, the battery ignition-system has about the same weight as the double-magneto installation.

IDEAL IGNITION-SYSTEM

Based on the requirements of the types of military and commercial aircraft now in service and proposed for the future, the ideal ignition-system should have the following characteristics:

(1) A rugged light compact source of sparks
(2) Flange mounting
(3) Bearings large enough to allow a direct splined shaft or gear drive
(4) Complete enclosure of the ignition system in a metallic housing conforming to the space available on the engine
(5) Secondary cables carried in substantial metallic housings preferably built into the cylinder-block and connected directly to the distributor housing, without flexible braid or tubing, thus providing radio shielding and mechanical protection and eliminating the fire hazard
(6) Ignition drive from the propeller end of the crankshaft to eliminate drive stresses
(7) Ignition for starting direct from the "running" magneto without the use of booster magneto
(8) Electrical insulation for supercharging to at least 20,000 ft.
(9) A normal life, without lubrication, adjustment or cleaning, greater than the time between the major overhauls of the engine

(10) Accessibility in the airplane for inspection of breaker and distributor

(11) Easily removable and interchangeable breakers, condensers, coils, and distributor parts

(12) Standardization of the basic parts of a given make, such as main frames, coils, condensers, rotors, bearings, breakers, and the like, to make possible the use of the same parts with all types of engine

Many of these ideal features are yet to be realized, but the following may be considered as having reached a usable state of development:

(1) A reduction in the weight of the ignition system of from 25 to 40 per cent

(2) An increase in the satisfactory operating-speed of magnetos of at least 100 per cent

(3) Extension of the life of the magneto breaker at least five times

(4) Elimination of the fire hazard

(5) Direct drive without flexible coupling

(6) Flange mounting

(7) Air-gap distributor

In conclusion it must be emphasized that the development of ignition equipment specially adapted to aircraft engines has just begun. So far, the conventional single-magneto has the same general appearance as the first magnetos built. A glance at almost any aircraft engine gives a distinct impression that the ignition equipment has been hung on after the engine was finished. The double magneto is an attempt to adapt the ignition to the aircraft engine, but there are still possibilities of smaller and more compact units than any now available and of more serviceable installation on the engine.

FOREMANSHIP COURSES

THE Department of Manufacture of the Chamber of Commerce of the United States has issued a statistical report on the growth of foremanship courses in this Country. This states that the number of such courses, judging from the best figures available, has increased several hundred per cent in a year's time; also that, while it is true that there are still altogether too many who have not made definite plans, the tendency is to place the activity on an organized and permanent basis.

There are reasons for the rapid growth and permanent status of foremanship training. One company finds an increased production with a decreased personnel as the outstanding result. This it attributes to better foremanship. Another reports, through better cooperation on the part of the foremen, a considerably reduced inventory of material in process; a third has noticed closer cooperation between the foremen and the inspectors; another, less labor-turnover due to more intelligent handling of the human element; and still another, better employer-employe relations throughout.

Some baffling problems still remain. Accumulated experiences and results show that foreman training, to be most successful by the class or conference method, requires trained or expert direction. The large organization has work enough to keep one or more men busy all the time in improving foremanship and thus can have expert direction. But what about the smaller plant? If the company wishes to conduct its own foreman-training, at best, it must be directed as a by-product duty of some executive. He does not have time to devote study and thought to a proposition which must be handled with the greatest dexterity. In spite of these handicaps, some are succeeding, due probably to natural ability in this line. A man may be a fine engineer, he may be an excellent cost-accountant, or what not, yet a total failure in foreman training.

Of course, it is common knowledge that there are correspondence courses in foremanship, and these are naturally available anywhere. But if the company, or foremen's club in some cases, desires expert assistance outside of its own personnel in class or conference courses, the sources of such assistance are limited, particularly in some of the States. When the Chamber is asked by these smaller industries in these States "Where can we obtain assistance for foremanship improvement by the class or conference method?" it is limited to a very few names of institutions now offering instructional assistance by the methods they desire; while in other States the problem of the smaller organization is being fairly well cared for by existing institutions. In such cases one or more of the following agencies is usually functioning, and sometimes cooperatively: private agencies, city school system, State vocational education department, State university extension division, Young Men's Christian Association, chamber of commerce, local manufacturers' association, State manufacturers' association, trade associations, and other organizations.

The following are typical examples which are quoted in the report:

> At present the local Board of Industrial Education is cooperating with the Chamber of Commerce in conducting foremanship training with the assistance of the State university.

The City Safety Council is sponsoring evening instruction in foremanship for about 300 foremen.

> Does it, in the broad sense of the word, pay? We need not express personal opinion in answering this E. W. McCullough, of the Department of Manufacture, says. The answer comes continually from those who have had experience.
>
> Due to increased interest and fuller realization on the part of industry of the value of training for better foremanship the Chamber of Commerce of the United States has been able to list 324 courses that were conducted on an organized basis from June, 1925, to June, 1926.
>
> One executive comments:
>
> Much attention and study has been devoted to the development of automatic and labor-saving machinery. The human element in industry which has been neglected should now have equal attention, and the one big factor in human relations is better foremanship—better trained foremen.

The Effect of Wheel-Setting on Wear of Pneumatic Tires

By J. E. Hale[1]

Semi-Annual Meeting Paper *Illustrated with* Drawings and Photographs

ABSTRACT

THE author compares tread-wear of front and rear tires. Considering wear of rear tires as normal wear he analyses the abnormal wear observed on front tires and traces it to its causes, which are found to be camber, toe-in and imperfect geometrical layout of steering-arms and linkages.

A theory of the scuffing action is developed. It is due partly to various rolling diameters at different parts of the tire tread and partly to the setting of the two front wheels so they tend to roll in slightly different directions. Reducing the camber angle to ¾ deg. and the toe-in to 1/16 in., reduces both these errors and results in longer tire-wear.

No definite theory for camber is found. Toe-in depends on camber, counteracting the tendency of cambered wheels to diverge. A method is described for testing accuracy of rolling action by means of paper on a greased floor.

Service stations must be put in a position to test and correct toe-in and camber. Fine tie-rod adjustment should be provided in the design, and factory engineers should recommend only accurate and foolproof gages for this work.

Except for difference in degree these problems are alike on all classes of automotive vehicles and with all types of tires. Standardized settings of camber and toe-in would be very desirable.

Experience with "camber wear" is described in the discussion. An adjustable and graduated model for studying the effects of pitch, toe-in, camber, and caster is described and illustrated. Conclusions are drawn agreeing with those in the paper.

IT is generally known among automotive engineers that front-tire tread-wear often shows peculiarities that are noticeable enough to be called abnormal. In the case of rear tread-wear the rubber disappears by abrasion uniformly across the face of the tire, the rate at which this wear takes place depending upon the load, air pressure, character of road surfaces, speed, use of brakes, traction, tread design, quality of the rubber, and the cure. In the case of front tread-wear, in addition to all these factors excepting traction, there are possible effects from incorrect design or adjustment of camber, toe-in and steering geometry. Also, to offset the absence of traction, on front wheels there is the abrasive effect of the lateral scuffing resulting from thrust when making sharp or fast turns.

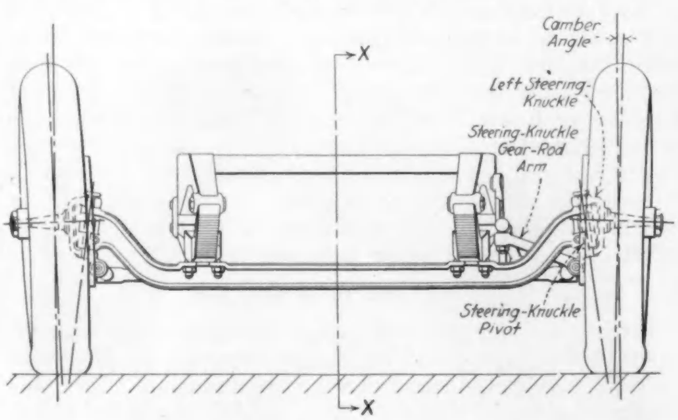

Fig. 1—Front View of Typical Chassis
Steering Elements Are Emphasized and Angle of Camber Is Plainly Shown

In studying this peculiar wear on front-wheel tires, we find cases in which:

(1) The center of the tread shows very little wear and the shoulders on both sides of the center show much wear
(2) The center and one shoulder show little wear and the other shoulder shows much wear
(3) Spots at irregular intervals around the tire are worn noticeably more than other parts. This is called "cupping" or "spotty" wear

These conditions of abnormal front-tread-wear are brought about by some scuffing action of a complex nature that is the result of interference from camber, toe-in or geometrical design of steering connections that prevents true rolling contact. That this is so is easily demonstrated by comparing the performance of tires made identical in every respect and run under comparative conditions on front and rear wheels.

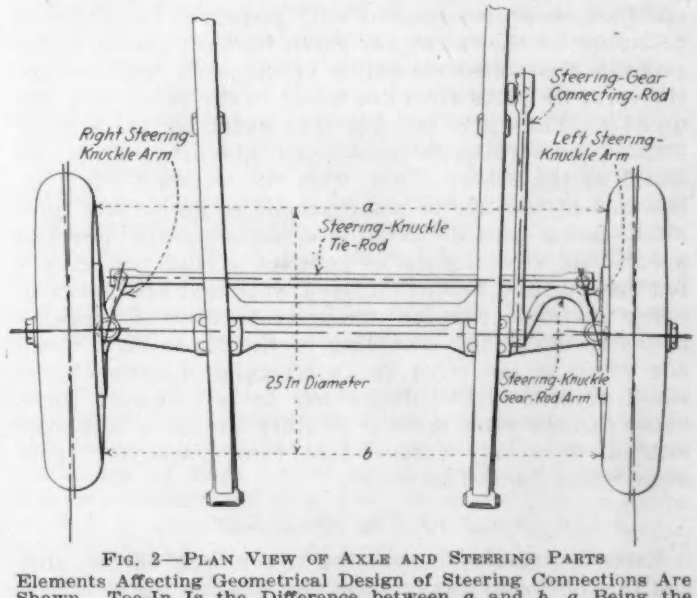

Fig. 2—Plan View of Axle and Steering Parts
Elements Affecting Geometrical Design of Steering Connections Are Shown. Toe-In Is the Difference between *a* and *b*, *a* Being the Greater

[1] M.S.A.E., Manager of development department, Firestone Tire & Rubber Co., Akron, Ohio.

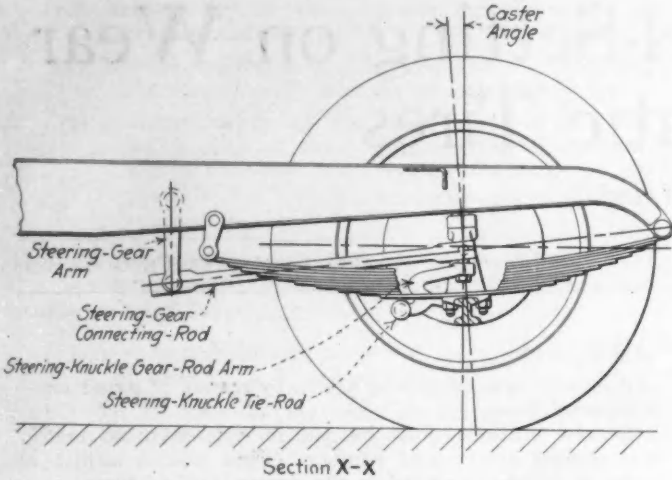

FIG. 3—SIDE ELEVATION OF FRONT OF CHASSIS
In This View Are Shown Caster Angle and Connections from the Front Axle to the Frame and to the Steering-Gear

The front end of a typical chassis is shown in the three drawings, some of the parts being eliminated to emphasize the steering elements and other features that affect the position of the front wheels. Camber is indicated in the front view, Fig. 1; toe-in appears in the plan view, Fig. 2; and the caster angle is shown in the side elevation, Fig. 3.

No Mathematical Analysis

We have found no scientific way of investigating the unnatural movements of the wheels that are responsible for this tread-wear, but we get a fairly clear conception of the situation from simply reasoning it out. There must be a combination of lateral scuffing and circumferential slipping in certain zones of the tread while other zones are advancing by true rolling contact.

When either or both of the front wheels roll in a plane at an angle from the direction in which the car is moving whether running straight ahead or turning, the result is a definite lateral friction component which tends to deflect the tire laterally. The tire yields to a certain extent, but since the wheel is forced to advance continuously under these conditions the frictional resistance of the rubber is overcome and lateral scuffing results. It is probable that only one of the front wheels is toed in or out from its proper position with respect to the direction of motion of the car at any given instant; and it is also probable that under conditions of changing road surface, the error switches from one wheel to the other very frequently. Thus it is possible that under certain circumstances the scuffing is transferred alternately from one wheel to the other. This, with the constant effort on the part of the tire to restore itself to its natural form after having been distorted laterally, obviously provides a sufficient combination of complex actions to account for the several different forms of wear that are observed.

For instance, cupping or spotty tread-wear probably is the result of the switching of the toe-in error from one wheel to the other in an irregular manner as the wheel rotates. This simply has to be repeated times enough in the same manner to start low spots, and once started, it is only natural that these particular spots grow worse instead of better.

Effect of Too Much Camber

Excessive camber causes the tire to run on one side and this obviously exaggerates the wear on the shoulder. There is the added complication of the great discrepancy between the diameters at the center of the tread and at the edge of the shoulder. Under these conditions the center of the tread dominates the situation by assuming what is approximately true rolling contact, while the extreme shoulder portion must slip because of its smaller diameter, and the slipping manifests itself in excessive shoulder-wear.

In order to prevent abnormal tread-wear on front wheels, it is necessary to design the car so that it has rolling contact at all times strictly in the direction of the plane of the tire and with no lateral scuffing-components. To accomplish this it is desirable to have the front wheels straight up and down, with no toe-in when running forward and with the steering geometry worked out so that, in steering to either side from the straight ahead, the direction of the wheels is such as to cause no toe-in or toe-out component.

In the testing done under my observation we have used a camber of 3/4 deg. and a toe-in of 1/16 in. The improvement was so marked that I am inclined to advocate these figures for consideration as a standard. These seem to me reasonable figures for all-around use, to get the wheels nearly straight up and down and running almost straight ahead. Expressions of opinion received in correspondence indicate a general concurrence with the idea of working along this line. The precise figures recommended for camber and toe-in, however, varied somewhat. Having in mind the simplification of service recommendations throughout the Country, I hoped that a simple standard of toe-in and camber could be recommended universally, believing that, if it were generally known that a certain angle of camber and a certain degree of toe-in are proper for all classes of vehicle and all types of tire, such a standard would be adopted for adjustments in restoring vehicles in the hands of owners to the proper condition.

As I understand it, toe-in and camber are co-related and must be considered jointly. In my correspondence with the car, truck and coach designers, their replies leave with me the impression that there are no clear-cut theories as to the importance of camber. Camber seems to be considered necessary, and in the past an angle between 1 1/2 and 3 deg. has been used. Toe-in seems to be less on the designers' minds, but in a general way is considered desirable as a correction to counteract the effect of the camber angle that has been adopted.

A Test for True Rolling

Rolling contact without lateral scuffing when making turns must be provided for in the steering geometry as well as in the toe-in and camber combination. I am informed that some engineers have studied the geometrical elements, including tie-rod length, distance between knuckle pivot centers, and length and angle of knuckle arms, by laying oiled paper on a vaseline-covered floor. One front wheel of the car is pushed repeatedly over this paper and adjustments of the geometry are made until an arrangement is found that will not disturb the paper. It seems impossible to find the correct geometrical arrangement in layouts on the drafting board but, once the correct combination is found by this oiled paper method, it may be measured and applied to production practice. After checking many cars with the three-way wheel-aligner, it is my belief that very few cars in the hands of owners today will pass this test except those that have been designed in this way.

I believe that it is desirable to stress the need of putting the service stations in position not only to adjust toe-in, but to correct the camber of axles that have been

put out of adjustment by bending or wear of the parts, and also to restore the geometry. Once the correct camber, toe-in and geometry have been determined for any given car, they should be recorded in the instruction books in such a way that they may be available for use with the various toe-in and camber gages on the market. I believe that for all technical discussions toe-in should be measured at the extremities of 25-in. diameter, and for practical application in service it should be listed as it would be measured by each of the different toe-in gages available on the market.

Fine Adjustment Should Be Possible

I would like to emphasize the need of accurate provision for adjustment, particularly of toe-in. The features of the tie-rod design that provide for this adjustment should be modified wherever necessary to provide a considerable degree of refinement. I mention this because the thought was expressed in some of my correspondence that close adjustment is not necessary. I would also like to emphasize the fact that factory engineers should familiarize themselves with the various toe-in and camber-adjustment gages that are on the market to be sure that they recommend only those that are really suitable to make accurate measurements and fool-proof enough to work satisfactorily in the hands of service-station mechanics.

The thoughts in this paper have been given in a more or less abstract way as it is my belief that they apply to passenger-cars, motor-trucks and motorcoaches, to balloon, high-pressure pneumatic, solid, and cushion tires. The unnatural front-tread wear does not manifest itself in precisely the same way with these combinations of tires and vehicles, but in the long run they are so closely related that it is fair to say that it merely presents itself in a more aggravated form in one type than in another.

In conclusion, I feel very strongly that it would be desirable to have standard figures for toe-in and camber, if that is possible. However, it may be that some research will be necessary first and this research may show that we need a formula, not a standard. However that may be, I believe that the camber, toe-in and steering geometry of the front axle merit more consideration than they have had in the past, and that proper attention to these points will contribute another refinement to motor-car design.

[2] Technical engineer, highway transportation department, Goodyear Tire & Rubber Co., Akron, Ohio.

Fig. 4—Tire Worn by Excessive Camber
The Greater Wear at the Nearer Side of the Tread Is Apparent

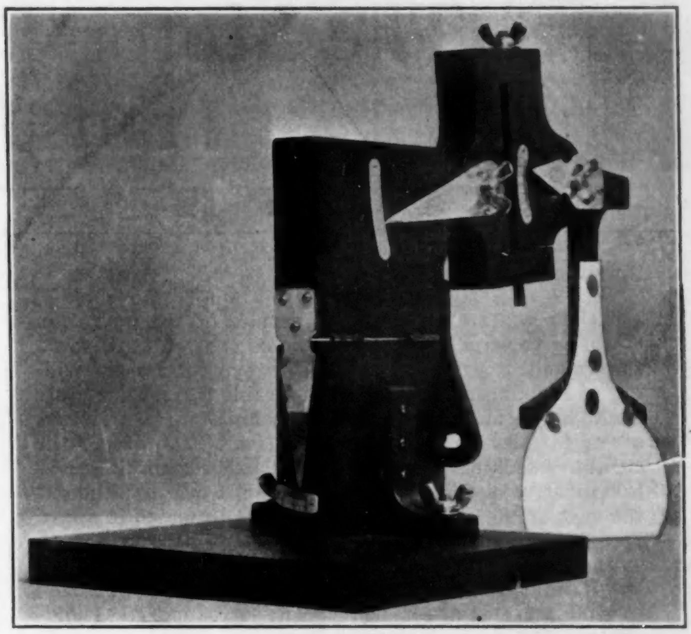

Fig. 5—Adjustable Model for Study of Front-Tire Contact
Adjustments and Pointers with Graduated Scales Are Provided for Pitch, Pivot Angle and Camber. The Tire Section Shown Tacked in Place Is Marked as Representing a 36 x 8.25-In. Tire with 5⅝-In. Wide Contact With the Ground, Corresponding to 2500-Lb. Load at 45-Lb.-per-Sq.-In. Inflation-Pressure

THE DISCUSSION

G. M. Sprowls[2]:—We had a bad case of the so-called "camber wear," the results of which are shown in Fig. 4. It was forcibly brought to our attention on an interurban motorcoach that was covering about 200 miles per day, mostly on low-crowned concrete roads. The front tires of this coach were worn through to the breaker-strip on one side of the center of tread in about one-third of the mileage that might be expected from it. We checked up the camber and found it to be 3 deg. Toe-in, measured 9 in. above the ground and at the center of the cross-section of the tire, was ⅛ in. Caster angle was 1½ deg.

We conferred with the engineer of the company manufacturing the chassis and showed him a section of the tire with the abnormal tire-tread wear and he changed the camber angle from 3 to 1½ deg. We know of at least two companies which have reduced from 3 to 1½-deg. camber.

It was difficult for us to visualize just what action took place when turning, at which time changes occur in the camber, caster and other angles. To demonstrate the action we made a small wooden model of a front-axle steering-knuckle and section of wheel and tire, as shown in Fig. 5, with the caster, king-pin and spindle angles and toe-in all adjustable. The model has graduated

(Concluded on p. 48)

The Motor-Truck's Place in Transportation

By F. I. Hardy[1] Transportation and Service Meeting Paper

ABSTRACT

STUDY of the methods and results of the operation of motor-trucks in various fields showed that, while the various sources of possible information were willing to help, no accurate or comparable figures for costs could be obtained because of incompleteness and lack of uniformity in accounting systems. Therefore, the Boston & Maine Railroad began experimental operation of trucks in several classes of work to find out the cost of the service and the extent to which it might be useful to the railroad.

The motor-truck has a big place in transportation but it is still a great question for transportation men to find just what service it can perform to best advantage, to avoid economic loss. The problem is too complex for the general public to solve, although the ultimate approval of the public will support the right solution. The shipper will not solve it because transportation is a minor problem with him.

The operator of trucks for hire is vitally interested in costs but his experience is limited and he often builds on inaccurate data, sometimes on misrepresentation. His activities have challenged the efforts of other transportation men but he is not qualified to lead in the solution of the great fundamentals.

The truck manufacturer has produced a wonderful machine and has built up a technical organization second to that in no industry, but he has generally sold only trucks, not transportation. He is under obligation to work for a stable trucking-industry.

Railroads have had many years of transportation experience and are now studying the needs of the shipper and devoting themselves to his service as they did not formerly. They too have a great organization of specialists and technical men, and are obligated to the public. Therefore the responsibility for solving the basic problems of transportation by motor-truck rests upon the truck manufacturers and the railroads.

Questions of size, equipment and operating radius are important details, but they may be answered differently in different localities and are unimportant beside the basic principles of transportation. The interested parties are earnestly trying to solve the problems and will make more rapid progress if they concentrate on the one fundamental of learning what shipping can be done more economically by rail and what by motor-truck. To ignore this is to court disaster.

In the discussion it was suggested that the Society propose a method by which a board could audit the figures for capacity, cost and performance that are submitted by salesmen to prospective purchasers to see that they are based on operating conditions rather than on test conditions that cannot be reproduced in operation.

The laxity of accounting of many truck-operators was confirmed. The total cost of a truck cannot be determined until it has been scrapped. Overhead costs vary so much because of conditions other than the equipment that truck makers are advised to list overhead separately.

Emphasis was repeatedly placed on the importance of working out the fundamental problems, and a joint board was proposed for their consideration.

BEFORE the Boston & Maine Railroad entered into any activities in the motor-truck field, comprehensive studies were made in each of the motor-truck fields, that is, store-door or local delivery, over-the-road service, so-called long-distance service, and the transfer of heavy tonnage between terminals, whether between the railroads and the steamboats or between the terminals of the railroads. It did so because it felt, after a thorough investigation, that little was known of the real facts regarding the economies that could be effected and the costs of operation in the various fields, and that motor-truck operation could progress only so far as it was proved to be economic. The growth must necessarily be slow, because the railroad had to secure most of the information for itself.

Everyone concerned, however, truck operators, truck manufacturers and other railroads, was very kind in giving information and in helping; but information as to truck operation and cost was very indefinite and vague and, in many cases, not comparable, because the various interests involved did not take the same factors into consideration.

Boston & Maine Begins Truck Operation

Going briefly into our small operation, a little more than a year ago we began to make store-door deliveries in Boston and Lawrence. The operation was small and is still small. We believe, however, that we have acquired some pertinent facts and some very definite information as to the cost of operation, the reasons that we have not grown more rapidly and how to grow if it is necessary. We believed that it was important to find out whether it was necessary to have store-door delivery in any or all the cities. How to find out that fact was what we were trying to do. We experimented on the road trucking, and, as a result of these operations, we think we have some insight into our proposed future policy.

Our operation in transfer tonnage in the city of Boston is only about 350 tons a day, but that, too, has been mainly for our education; and we think we have learned a great deal about it.

I do not think that anyone will seriously question the permanent place of the motor-truck in the transportation field, considering the age of this industry and the great amount of money invested in it, approximately $800,000,000 in trucks alone, plus many millions in garages and auxiliary equipment; and this great investment has been made within only a few short years.

What are its advantages as compared with other modes of transportation? They are speed, small units, the fact that shipments ordinarily do not have to be packed as well as for railroad movement, and that shipping by truck is supposed to allow the carrying of lower inventories because of quicker movements.

Surely, this business could not have grown so rapidly

[1] Assistant to the president, Boston & Maine Railroad, Boston.

and to such vast proportions unless its service in some instances was superior to any other form of transportation. To my mind, the permanent place of the motor-truck in the transportation field is one of the greatest questions that transportation men must face in the next few years, and it must be answered within a reasonable time in order to avoid great economic losses to the public, the trucking industry and the railroads of this Country. It is not my purpose to answer this question. I do wish, however, to call attention to certain factors, the prevailing practices and the prejudices of the various interests that must be considered in answering this question.

Who Will Establish Fundamentals?

Let us consider the interested parties: (*a*) the general public; (*b*) the shipper, including those who ship in their own trucks; (*c*) the owner of trucks for hire; (*d*) the truck manufacturer; and (*e*) the railroads.

In the order in which I have mentioned them, let us consider first the general public. The general public cannot be expected to solve the problem because of the complexity of it. Transportation is one of the most complex of all human endeavors. It is the one science, some persons will not call it that, on which all others depend and without which none can progress. Modern conveniences, whether they be the electric light, the telephone, gas, water, or the radio, cannot continue to progress without the best of transportation. Any great public utility can progress only in proportion to the adequacy of transportation facilities and the progress and improvement of them. It touches so many phases of human endeavor, as compared with almost any other business. Civil engineering, electrical engineering, mechanical engineering, accounting, merchandising, law, medicine, chemistry, in fact, all the sciences enter into it.

Trucking is one of the most complicated of the transportation units because of its great flexibility in its given field and because of the smallness of the unit. But the American public generally decides every question about right. While the decision is being made, certain portions of that public and of the people who are serving it are injured. We are inclined to swing from one extreme to the other; but we can depend upon the public, when it has the true facts, to be a fair judge and to make fair rules and laws under which the problems will be worked out; and it is only by giving the public generally the facts that we can enable our judge, the general public, to work.

When Speed Is Economy

The primary interest of the direct shipper is good transportation, which nearly always means, in his mind, the most economical shipping. This does not always mean dollars and cents, but economical, all things considered. It may be economical because it allows him to operate a plant in competition with some other plant because of its speed, not because of the rate per 100 lb. of freight movement. To his mind, that is economical.

Present operation of trucks, however, has not always been for that reason. Truck operation received a great impetus forward during the war, because it was necessary to use every facility that could be thought of. The owner began trucking, and the shipper began trucking, because it was the only method of keeping the plant in operation and of supplying the necessary goods to customers. They have had to continue in many cases, however, where it is not economical, for the reason that they have had to use the investment they have made.

I wish to call attention to some of the instances that have come to us. The traffic manager of a concern that has required a great deal of trucking during the last 5 years and does not own a single truck told me some months ago that the company had got its goods trucked during the last 3 years for $75,000 less than the actual cost of trucking. I asked him if he thought that would continue and if he thought it good business. He said he thought it was good business and, so long as he could get someone else to give him $25,000 a year, he would not buy any trucks or use any other method. Admitting that to be true, some lines are practically public carriers and many in the State of Massachusetts and adjoining States have gone into bankruptcy or have changed ownership three or four times in a year.

We must remember that transportation is generally only a minor part of the business of the shipper-owner of trucks and that he looks at it only as it affects his particular business and not in a broad sense, as affecting the public. His field is limited in helping to solve the problem.

This leaves three parties whose sole business is transportation and on whom most of the responsibility for the solution of the truck's place in transportation rests. First, the owner of trucks for hire. His experience has been somewhat limited because his field is narrow. He has not had facts on which to establish firmly an economic business, except the facts that were supplied by someone else. I am not ready to say that he has been purposely misled and misinformed, but the people who have sold him the equipment have not been able to give him the facts on which to establish a sound business. In a few cases, I am afraid the effort has not been made to give the facts.

Truck-Selling Methods

As an instance of this kind, only a short time ago, a man came to our office and offered to lease to us for a period of 6 months three 5-ton trucks with drivers at a rental of $17 per day per truck, knowing that our average daily mileage in this type of service is 59. Two days later, the truck manufacturer came in with a proposed purchaser of trucks who wished to secure a part of our business to have the prospective purchaser get a contract with us. He proposed to sell 10 new 5-ton trucks to this customer, who intended to pay, as the purchase price in cash, 25 per cent of the cost.

In the conversation, it developed that the customer had been given certain operating-costs; that he had been led to believe that he could go out anywhere and make a profit on the basis of the operating costs that had been given to him. In examining the figures presented by the truck manufacturer's representative, we found that he was proposing to have this man do part of the work for which he had sold the three trucks to the man who had been in our office a few days previously, and on a basis that would never allow the man to make the operating expenses less depreciation.

In the absence of the proposed purchaser, I asked the salesman if he felt that this was sound business, calling his attention to the man who had been in several days before and to whom he had sold the trucks, and asked him if he thought the trucking industry could continue to prosper. He said,

> Well, somebody will fool him; why not I? Somebody will make this sale. If I do not do it, somebody else will. I am only telling the story that the other truck salesman will tell him.

Is the truck operator for hire financially sound? Is he doing business on an economic basis? I do not need

to answer that question for those who are selling trucks, those who are hiring trucks or those who are actually operating them for hire. They know that a very large percentage of the business is not sound.

However, the truck operator-owner has done wonders in more ways than one. Among other things, he has made persons in other transportation fields sit up and study transportation as they have never studied it before. If he has performed no other service, that alone is a wonderful service and has been worthwhile, but the American public must pay for his mistakes.

Manufacturers Must Help Solution

The truck manufacturer is the second party. In a few years, he has produced a wonderful machine having wonderful possibilities in the transportation field. He is entitled to a great deal of credit. In many cases and to a certain extent, the manufacturer was pushed into the truck production by the war, but, nevertheless, he is in it, has done wonders and should not be deprived of credit simply because to a certain extent he was pushed into the field. But what has he been selling? He has been selling trucks and not transportation.

I do not mean that there are no exceptions to this statement in individual cases; but I am talking of the truck industry as a whole. Some companies, under financial difficulties and stress, have purposely sold trucks just to make sales, knowing that the buyer would lose all that he put into the trucking industry. Others have sold him trucks and have given him information that was faulty because they did not have the correct information. To my mind that has been the greatest difficulty; we have not had facts.

The business has grown so fast and sales pressure has been so great from this wonderful organization of manufacturers, from this great industry that has grown faster than any other industry in the world's history, that we have not had enough time. When we consider the great proportions to which it has grown, we realize that the manufacturer has not had time or has not considered it to be important enough to stop and look at the business in its larger phase. The business, to be sound, must sell transportation and sell it on a sound economic basis.

When all the interests affected are taken into consideration, manufacturers in the truck industry are a composite of a wonderful amount of science, chemistry and engineering and are as fine a group of men as any industry in this Country or in the world has produced. Therefore, a great responsibility lies on the truck manufacturers to help solve this problem, not for today, but, looking ahead 5, 10 or even 20 years, to the truck sales of tomorrow, and to think only of building a stable industry.

Railroads Also Must Help

Lastly, there is the railroad classification. Since the war, a great many railroads have begun to sell transportation. They were forced into it. Some of them have always sold transportation, but, because of truck competition, because of the belief of many railroad men that, if they did not sell transportation, the railroads would be taken out of their hands, they began to get down to the point where they studied the needs of the customer and sold transportation rather than the stock of their railroad. Consequently, they have become more prosperous, more useful. In my opinion, there is better understanding now between the railroads and the public than ever before in the history of America.

Some railroads have felt, and some still feel, that the motor-truck is an outlaw, that it has no place in the transportation field, that it is an enemy. Most railroad men feel, however, that if the motor-truck is an enemy it has already done about all that it can ever do as an enemy and that the only thing left for the trucking industry to do is to cooperate and coordinate with the railroads in giving service to the public.

The railroad men of this Country have had many years of experience in serving the public, are probably backward in many ways but have learned much about transportation. They, too, have a great group of men who are specialists in their fields, scientists and engineers in the various phases of their industry. They, too, have a great responsibility to the public, the same as the truck manufacturers. The two interests most responsible for the solution of the motor-truck's place in transportation are the manufacturers and the railroads.

Smaller phases of the problem are: What service should be performed by the motor-truck? How many miles should it run and can it run in long-distance service? What commodities should be handled by motor-truck? What size of truck should be used? Shall we use containers, roll-off bodies or trailers?

Solve the Essentials First

These are important details, but beside general principles they are insignificant. Real progress is to be made when consideration is given to the diversified interests of the industry. If one's money is invested in a particular type of trailer or body for truck operation, it is hard to be open-minded as to how it shall be used and what portion of the business shall be handled with that type of equipment. The same is true of every other manufacturer who makes a particular specialty, type or size of truck. Real progress is being made today as never before, in solving these problems because we are coming to realize that the type of equipment that best serves Boston does not serve best in Cincinnati. Say that store-door delivery is successful in Boston; it is not certain that it could be and should be successful in Chicago. We are reaching the point where we are analyzing the business as never before and realizing that, by a close cooperation of the interests I have mentioned, especially the last two, the problem, so far as that part is concerned, will be quickly solved.

There are evidences of the fact that all the interests are earnestly endeavoring to solve this problem. I am not pessimistic of the future or of the past, as to what has been accomplished or what will be accomplished. I am sometimes impatient at the speed of our progress; and I believe that all the parties concerned, especially the truck manufacturers and the railroads, in whom the greater responsibility lies, must ignore such petty phases of the problems as bodies, tires, chassis, store-door delivery, and what not, and strike at the fundamentals of the problem, because only by the most careful analysis can we consider the complexity of this business, and only by the close cooperation and coordination of our forces can the most economical transportation service be rendered.

The American public has a right to and will demand the best and most economical transportation. Any agency that fails to endeavor honestly to furnish that kind of transportation is flirting with disaster.

I believe that the problem can be satisfactorily solved if, after considering all these factors, methods, equipment, and coordination, we keep just one fundamental

in mind, namely, that the railroads, the truck manufacturers, the truck owners, and the shippers all should strive to learn the facts and to place on the rails the tonnage that should be moved by rail and on the trucks the tonnage that can be handled most economically by trucks, to the end that each and every one of us will be trying to sell the most economical transportation.

THE DISCUSSION

B. F. FITCH[2]:—I should like to amplify one thing that Mr. Hardy has said, based on my experience as an operator and previously as a salesman. The lack of standardization in the recognized and established capabilities of the motor-truck from an operating viewpoint and in claims made by the manufacturers are the most distracting things that can be put forth in sales arguments to buyers. A great many of those claims are false invitations to an inexperienced and gullible public.

As an operator, I have found out a number of things that I never knew as a salesman. My sales data on operating costs I thought were authentic. As a rule, the sales data were based on engineering tests. There is not a motor-truck manufacturer in the United States who cannot put his equipment on the road, run it for months and establish records that would be utterly impossible for any operator, employing available talent, to approach.

In road-test performances, 5 miles per gal. of gasoline is possible; I have done it myself. But if the selfsame truck is put into the hands of available drivers the 5 miles will shrink to $2\frac{1}{2}$ or 3 miles per gal. The same thing is true in maintenance charges. The peculiar thing in all sales analyses is the total ignoring of overhead and administrative expense. Some of these analyses have been turned over to me to be checked for reliability. In many cases, when the actual operating costs are placed alongside, the sales analysis shows less than 30 per cent of what the attainable practice cost would be. That seems a remarkable statement to make, but it is a fact.

Another unfortunate thing, especially in analyzing the opportunities of trucks in railroad service, is that truck salesmen do not know the railroad requirements. To estimate that 10 tons of the average run of merchandise freight can be carried on any truck unit that is within the allowable dimensions of motor-trucks in the majority of States in the Union, is preposterous. Merchandise freight cannot be loaded, on an average, more than 55 lb. per sq. ft. of floor area. To load on a truck 10 tons of diversified classifications, the unit would have to be about as large as a box car. To prove that statement, I should like to call attention to the average carloadings of merchandise by the railroads in the United States. The box car is a container as much as is a truck body or other type of transportation equipment.

I have recently received figures from one of the railroads that loads most intensively, a railroad that handles great volumes and has inbound and outbound records over a long period. It is loading $7\frac{1}{2}$ tons of merchandise into car units of approximately 2500 cu. ft. It is difficult, within the restrictions of maximum over-all truck-sizes, to get a body larger than 1000 cu. ft. How can anyone get 10 tons into 40 per cent of the space into which the railroads load but $7\frac{1}{2}$ tons?

A great many statements are made on the assumption that the operating unit will carry the rated load on each trip. When that is cut down 50 or 75 per cent, there is a vast difference; so I feel that, in addition to being an invitation to losses by ambitious investors, the sales prophesies have very much scrambled the opinions of railroad operators themselves as to what the truck can accomplish. Therefore, I think that if this Society could propose some method by which an auditing board could authenticate all these sales prospectuses before they are submitted to prospective customers and could see to it that they conform somewhat with reasonable attainments of the units in service, a great deal of the misunderstanding that exists between sales and operating organizations, particularly the railroads, would be wiped out. As a result the demands by users on the service departments of all the truck manufacturers would be materially reduced.

CHAIRMAN F. C. HORNER[3]:—I do not believe we will get very far in obtaining the cooperation of many of the motor-truck sales forces. However, I think the subject ought to be considered by the Society.

IRVING MALKIN[4]:—Mr. Hardy, speaking for the railroads, has touched on a most important subject. As I understand it, he has been a railroad man most of his life, but has lately been connected with the operation of motor-trucks. He has said that most of the operators engaged in the motor-truck business do not keep cost records, that they do not know the cost of operation, and that, naturally, many of them are just fly-by-nights.

I am a truck operator, have been operating for 9 years and am still in business. The motor-truck industry has developed fast. There is no question about that. But the motor-truck operators have been lax in keeping cost-records.

I have prepared a little pamphlet, with no intention of selling it to anybody, giving my 9 years' experience and showing the cost of operation of motor-trucks. In it is given an unbiased statement of the costs of 3 motor-trucks. I have kept accurate records from the moment I paid the first dollar on those trucks until they went to the graveyard. That is the only way in which one can tell the cost of operation. It is absolutely impossible on records for 1 or 2 years to get accurate costs.

The usual opinion of the railroad man and of some shippers is that the motor-truck operator is an irresponsible person. To a certain extent, he is a vagrant on the highways. We began to carry freight when the old form of transportation was not able to do it. I probably would never have been able to go into the motor-truck business if the railroads had been able to give service. During 1917 they were not prepared for the business. A shipper who has become accustomed to shipping goods by motor-trucks within a 40 or 50-mile radius will certainly not go back to the railroads.

Mr. Hardy made the statement that a man offered to give truck service for $17 per day. The quicker he accepted that offer, the quicker he would put the man out of business. I could not operate a motor-truck for less than $25.98 a day for operating expense and $9.20 a day for terminal costs, making a total of $35.18.

MR. FITCH:—Supplementing these comments, I should like to say that we keep exact costs and we find that standing time, with the driver on the seat and the engine running, costs $0.0416 per truck per min. When running, the additional wheelage cost, varying with the season and route, is between $0.27 and $0.42 per mile.

W. R. GORDON[5]:—Mr. Horner said that it might be difficult to get proper cooperation between the truck operator and the manufacturer. I think the latest develop-

[2] A.S.A.E.—President, Motor Terminal Co., New York City.
[3] M.S.A.E.—Assistant to the vice-president, General Motors Corporation, New York City.
[4] General manager, Motor Transportation, Boston.
[5] M.S.A.E.—Sales engineer, Pierce-Arrow Motor Car Co., Buffalo.

ments in the Society are in that direction, through the Operation and Maintenance Committee. I hope we shall get some real results from the work of that Committee.

A point raised by Mr. Fitch was that overhead figures are not always included in a statement of operating costs. I think it is a good plan to consider these figures separately, because they do not reflect accurately the operation of the equipment. The administrative expense on certain operations may be high or low but is not contingent on the type of equipment used. I think it is therefore good practice to consider this item separately.

CHAIRMAN HORNER:—I think Mr. Gordon is right. We ought to continue to hammer at the problem of getting the truck manufacturer, through his salesmen, to sell transportation instead of trucks. When competition stares one in the face, he is likely to resort to methods that will not bear close analysis; but the trend is in the other direction.

F. J. SCARR[6]:—I should like to congratulate Mr. Hardy not only on his address but on the work he and his associates have been instrumental in performing. It was my pleasure 2 years ago to talk to Garrett Fort, who made the statement:

> The Boston & Maine has grown weary with waiting for other railroads and other persons to act as its experimental transportation laboratory.

Since that time, the efforts and the accomplishments of the men of that road bear witness to the determination and mature thought behind that conclusion.

MR. HARDY:—The question is not whether or not we will have store-door delivery. We already have in the United States the greatest store-door delivery in the world. The question is who will perform that service? We cannot answer that by bickering whether it shall be with a roll-off body or a container lifted with a crane. We must get back to fundamentals. There are wonderful possibilities in roll-off bodies, but whether they are the most economical, I am not able yet to determine. When a truck man talks of cost of operation and says $40 a day, he may be handling feathers and I want to handle pig iron. They cannot be handled for the same amount. The question is broader than that.

The only hope of getting speedy action in this matter is to bring the interested parties together on fundamentals, remembering that it does not make any difference whether Chicago merchants want store-door delivery and whether they wish it to be performed by the railroads or by private individuals. What they will finally have will be the most economical store-door delivery, whether or not you or I want it. That is governed by the laws of economics as they apply to this situation.

We must get back to the fundamentals of selling transportation, and that means economical transportation. If five broad-minded men from the railroad field, five men from the truck manufacturers and possibly five who represent the largest trucking companies in the Country and have made the greatest study of trucking, should meet for 3 days, lock the doors and let no one out, they would agree on the fundamentals that will start this business of coordination on the upward trend. In 3 days, they would do more than we can do in 5 years in the way we are working today.

CHAIRMAN HORNER:—That is a fine idea! Why can we not do that? Get five outstanding men in the railroad field and five in the automotive industry, put them into a room and lock the door?

MR. MALKIN:—It sounds very well, to say five railroad men and five automotive engineers, but I challenge them to get anywhere if they do not include representative motor-truck operators.

CHAIRMAN HORNER:—I referred to five railroad men and five from the automotive industry; I do not mean manufacturers, although some of those who now happen to be in the manufacturing business have had experience in operating motor-trucks as well. Saying five experienced and well-informed men from the railroad fraternity and five from the automotive industry covers a great deal of ground. It is an excellent idea. I should like to have someone offer a resolution about this to be placed before this Society, requesting it to appoint a committee to confer with some of the railroad men who are really looking forward in this matter and trying to solve the fundamentals. It might be well to have this Society and the Railroad Motor Transport Conference confer on this question and see what could be done. That would be a very constructive thing to do. I should like to compliment Mr. Hardy on bringing this matter to our attention in so fine a way.

[6] M.S.A.E.—Supervisor of motor service, Pennsylvania Railroad, Philadelphia.

EFFECT OF WHEEL SETTING ON PNEUMATIC-TIRE WEAR

(Concluded from p. 43)

scales for indicating any desired angles under study. This permitted us to visualize the wiping action of the tire under various angle conditions much better than a number of drawings. It further led us to speculate as to what the results would be with an axle having no camber. Two axles were made up with no camber, by cold bending the axle centers.

In the meantime, the 1½-deg.-camber axles had been placed in service and showed considerable improvement over the 3-deg., but the no-camber axles showed much greater difference from the 1½-deg. than the latter had from the 3-deg. axles. With no camber there was no indication at all of camber wear, and mileage even in excess of what might have been expected was secured from the tires. It seemed at first that a no-camber axle would cause the vehicle to steer hard but drivers reported that it steered very easily, even more so than the 3-deg. camber axle.

While all the above statements refer to experience with motorcoach chassis, we see no reason why it should not apply to passenger-cars.

We are not necessarily recommending axles with no camber but we do believe that anything that can safely be done to reduce slippage between the tire and road surface will result in greater tire mileage and reduced operating expenses.

Effects of Legislation on Design of Automotive Vehicles

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SEMI-ANNUAL MEETING PAPER *Illustrated with* DRAWINGS

ABSTRACT

NORMAL development of the motor-vehicle has been interfered with very little by legislation and regulation, as the motor-vehicle was originally built for and has since been produced principally for private use. The great increase in the number operated, growing use of motor-trucks and motorcoaches, the consequent congestion of traffic, and the mounting cost of highway construction and maintenance have, however, made necessary the enactment of laws and the enforcement of regulations for protection of the public interest and safety. Control of the operation of motor-vehicles on the public highways is vested chiefly in the State legislatures, which delegate certain regulatory powers to State commissions. Legislative bodies are slow to set in motion and, once having enacted a provision, it is a difficult and slow process to induce the legislature to rescind or change it. Regulations, on the contrary, may be changed with relative ease and expedition.

Lack of uniformity among the State motor-vehicle laws presents one of the greatest difficulties that confront the automotive industry and has an obstructing influence on improvement in design of the vehicle and its equipment. Passenger-cars have been least affected, but the long-stroke engine is a direct development resulting from the almost universal imposition of license fees or taxes on horsepower calculated on cylinder-bore. The problem of satisfactory headlighting has been complicated by the great diversity of State requirements and restrictions, which are stated in the paper and shown graphically in drawings. Brake and braking requirements are couched in general terms in the laws and are indefinite in meaning.

Large heavy vehicles, as motorcoaches and motor-trucks, are affected most seriously by legislation and regulation. Their over-all length and width, and their gross weight with load, are variously restricted by different States. The intent of the legislators, sincere but misinformed, is to preserve existing highways and minimize danger to all users by forcing the use of smaller vehicles. The restriction of gross weight is asserted to be uneconomic, as it encourages overloading and does not decrease the total volume of goods hauled but makes a larger number of vehicles necessary to carry the tonnage. This increases the tare weight, adds to traffic congestion and induces higher operating-speed. Limitation of weight per axle or per inch of tire width has fostered development of the six-wheel vehicle and the use of the tractor-semi-trailer combination.

The tendency to interfere by legislation and regulation with design and construction instead of specifying the results to be obtained is fraught with disquieting possibilities. Concerted research and educational effort on the part of all elements of the industry and cooperation of engineers with representative bodies seeking to bring about sensible and uniform requirements and restrictions are needed to bring the light of engineering fact and economic reason to bear upon public relations.

IN the development of the modern motor-vehicle the automotive industry has been favored exceptionally by the minimum of regulatory interference with normal evolution. Originally developed and ever since produced principally for private use by independent owners, the motor-vehicle has been largely unhampered by the sort of legislative restraint which has marked every step of the progress of the older forms of mechanical transportation media, such as steam and electric railroads and steamships. Since the earlier days of civilization, the highway has been common property and its free and unrestricted use is one of the oldest and most cherished rights of the citizen.

It is doubtful if even now governmental control of motor-vehicles and their operation would be more than nominal were it not for their widespread popularity, the traffic and highway problems which have arisen therefrom and the almost limitless adaptability and flexibility of the motor-vehicle, which have led to its growing application to common-carrier services. But with the growing expenditures for highways, the increasing complexity of the traffic problem, the alarming proportions of the daily-traffic casualty-record and the intimate relationship which highway transport is assuming with almost every line of commercial endeavor, government has taken cognizance of the complex civic problem to which the motor-vehicle has given rise.

Large unwieldy bodies, such as the machinery of legislation and regulation, are slow to set in motion and extremely hard to arrest when once started. Legislative activity in relation to the motor-vehicle has gained such momentum today that it is now the intimate concern of almost all elements of the automotive industry. It has, naturally, centered chiefly about the larger and heavier vehicles and those which are used in common-carrier service. These are today of minor importance in the industry, but in their potentialities they represent the most promising types for rendering public service; consequently the effect that legislation is having and seems likely to exert on these classes of product should be of particular concern to the automotive engineer.

VEHICLES GOVERNED BY LAWS AND REGULATIONS

Legislation to protect the public interest becomes necessary whenever mechanical developments result in the creation of devices of widespread potentialities both for good and, if abused, for evil. Such legislation as has affected the motor-vehicle has ample precedent in long-established laws affecting and regulating building construction, steamship registry and operation, railroad

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operation, public utilities, and so on. The right of government to regulate and tax motor-vehicles is today unchallenged, nor would it be consistent with established public policy to allow motor-vehicles to be built and operated without some statutory safeguards for the public. The public welfare is concerned in a variety of ways, which may be classified in three main groups: (*a*) the right of citizens to a fair and equal opportunity to enjoy the use of motor-vehicles, (*b*) the protection of public property as represented by highways and bridges and (*c*) the promotion of public safety and health.

As a result of the necessity for such legislation, the development and extension of the motor-vehicle industry has given rise to a variety of governmental regulations of two main types: (*a*) outright legislation and (*b*) regulation. Legislation has been directed, as a rule, toward the establishment of certain rules for safe and reasonable operation of motor-vehicles, having as its object the assurance of orderly, safe and equitable sharing of highway facilities by motor-vehicle drivers and other users of the highway, and the imposition of license fees and taxation to defray the expenses of proper administration of such legislation and as recompense for highway expenditures made necessary by reason of motor-vehicle traffic.

Design Affected Most by Regulations

Regulatory authority usually is exercised by virtue of general provisions in existing law or special legislation of enablement. In general, legislative enactments have had little effect upon the development of automotive design and it may certainly be said that motor-vehicle evolution has proceeded quite independently of legislation. By reason of its effect on the market for certain types of vehicle, however, legislative weight-restriction has had a potent indirect influence on the design of these types. Regulation within recent times, on its part, has begun to exert an increasingly powerful direct influence on the design and construction of certain classes of automotive equipment. Fortunately, that species of government activity which directly affects design and construction has been confined principally to the regulative function, so that the flexibility which is so essential in the control of a rapidly-developing industry, and which would be sadly lacking were such efforts of a legislative nature, is largely preserved.

Long-Stroke Engine Due To Horsepower Tax

One of the more notable exceptions to the general tendency in this respect is, curiously, one of the oldest motor-vehicle legislative provisions now in force; namely, the basis upon which taxation of motor-vehicles is imposed. More than 20 years ago in England, France and Germany, taxation of motor-vehicles was established on an arbitrary horsepower-rating based on the then imperfectly understood factors governing the horsepower of internal-combustion engines. This basis differed but slightly among the countries named and has been copied rather universally throughout the world. On the basis established the horsepower tax is calculated on the bore of the cylinders. Designers abroad were quick to take advantage of this by developing engines of the long-stroke type, wherein the displacement necessary for adequate horsepower might be secured with the minimum bore and therefore be operable at the minimum tax.

It may be said that this piece of legislation has had the most profound influence upon the design of all motor-vehicles of all laws so far enacted. Whether the present prevalence of long-stroke engines would have been realized through normal development without this artificial stimulus is open to question, but present thought along this line seems to indicate that, in certain types of powerplant at least, unhampered evolution might have resulted in a more rational compromise between bore and stroke than is evident in many cases today.

States Most Active Regulatory Bodies

In this Country motor-vehicle legislation and regulation may be enacted by the Federal Government, the various State and territorial governments, the counties, and municipalities. So far the Congress has not seen fit to undertake regulation of motor-vehicles beyond the imposition of certain excise or sales taxes. In the last few years, however, the regulation of interstate motor-vehicle traffic has been the subject of nation-wide hearings by the Interstate Commerce Commission to ascertain the facts with respect to this form of transportation.

Most of the motor-vehicle legislation and regulation has so far been enacted by State governments in the form of motor-vehicle and highway laws and by State commissions in the form of regulation of common carriers. Municipal governments have also, in many cases, passed ordinances regulating operation and in some cases imposing a wheel tax. In a few instances city authorities have gone so far as to pass regulations requiring certain types of equipment for motor-vehicles, but this has by no means been general. County authorities usually are barred by State enactment from regulating motor-vehicle traffic, although in some States county highway boards are given the power to exercise authority over the weights allowed on certain types of road and bridge.

It is, therefore, with State legislation and regulation that we are concerned principally. Under the highway laws of the various States, registration is usually delegated to the Secretary of State, to a motor-vehicle department or to a State tax commission. The motor-vehicle statutes set forth the allowable speed, weight and size of the vehicles and generally include provisions regarding lighting equipment, horns and braking requirements stated in very general terms. Regulation of common carriers, particularly of motorcoaches, usually is in the hands of public utility commissions, which are also empowered to promulgate regulations relating to structural features and equipment of motorcoach chassis and bodies.

Passenger-Cars Affected as to Lighting

Different types of motor-vehicle fare very differently under the laws and regulations of these various authorities. Passenger-cars are least affected, particularly as regards design and construction. In their own class they are most affected in the matter of lighting equipment, and head-lamps are part of the lighting equipment upon which most emphasis has been placed. Almost every State has some definite requirement as to headlighting, and these requirements vary all the way from the mere provision that a white light must be displayed at the front of the vehicle from sunset to dawn to highly technical specifications on illuminating power and distribution of light. Some of the principal variations in headlighting requirements in the different States are shown in Fig. 1. The requirements for a head-lamp that would be legal in all States are shown in Fig. 2.

These requirements and their lack of uniformity have caused a great deal of trouble in the motor-vehicle in-

dustry because engineers have so far been unable to arrive at any agreement as to what constitutes the best head-lamp construction. Much investigation is now going on and a great deal of information has been compiled as a result of research and experiment. From this it is apparent that hard and fast rules written into State laws at this time are a hindrance to ultimate solution of the problem, and that to the extent that they complicate normal progress they may operate to the prejudice of the public welfare which it is their purpose to promote. It is therefore to be hoped that State legislatures will withhold rigid legislation on this subject until more can be learned and engineering talent now devoted to the problem can agree upon a uniform program.

Research along this line is being prosecuted with vigor. Such organizations as the National Electric Light Association, the Illuminating Engineering Society, the Bureau of Standards, and the Society of Automotive Engineers have been exceedingly active in the last 2 years, in addition to which the attention of scores of engineers and corporations working independently has been attracted to this problem. In recognition of the difficulties involved, 10 of the Eastern States have organized the Eastern Conference of Motor-Vehicle Administrators. This Conference has agreed upon standard methods of testing head-lamps and has selected certain types which comply with the laws in the States represented. The motor-vehicle commissioners have approved these types for use and issued uniform regulations for the focusing of head-lamps. Thus motorists in these States may operate such standard headlighting

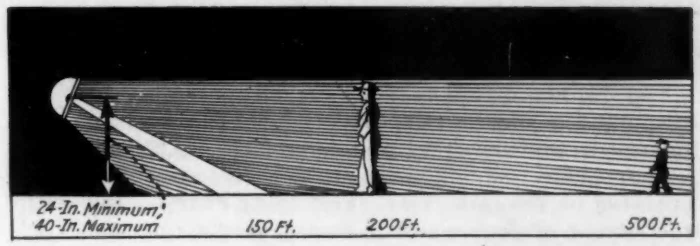

FIG. 2—HEADLIGHTING THAT IS LEGAL IN ALL STATES
To Be Acceptable in All States the Head-Lamps Must Be Located with Their Centers from 24 to 40 In. above the Road; the Concentrated Beam Must Not Rise above the Surface of the Road at a Distance of More than 150 Ft. Ahead; Objects Must Be Made Visible to the Driver at a Distance of 200 Ft.; and the Headlight Must Be Visible from a Distance of 500 Ft. Ahead

equipment freely throughout the Eastern region while at the same time a way is left open for modification of the headlighting regulations uniformly throughout these States as new developments indicate their desirability. In this case, as in many others wherein regulatory activity must of necessity proceed concurrently with the development of the art, the principle of regulation by commission rather than by inflexible statute is proving, and will prove to be, the best solution.

BRAKE-DEVELOPMENT RELATION TO STATE LAWS

So far very little regulation of a definite nature affecting brakes has been enacted. Most of the laws simply require that the brakes be adequate to stop the vehicle in all circumstances. Some States, however, have gone further and require that the vehicle be equipped

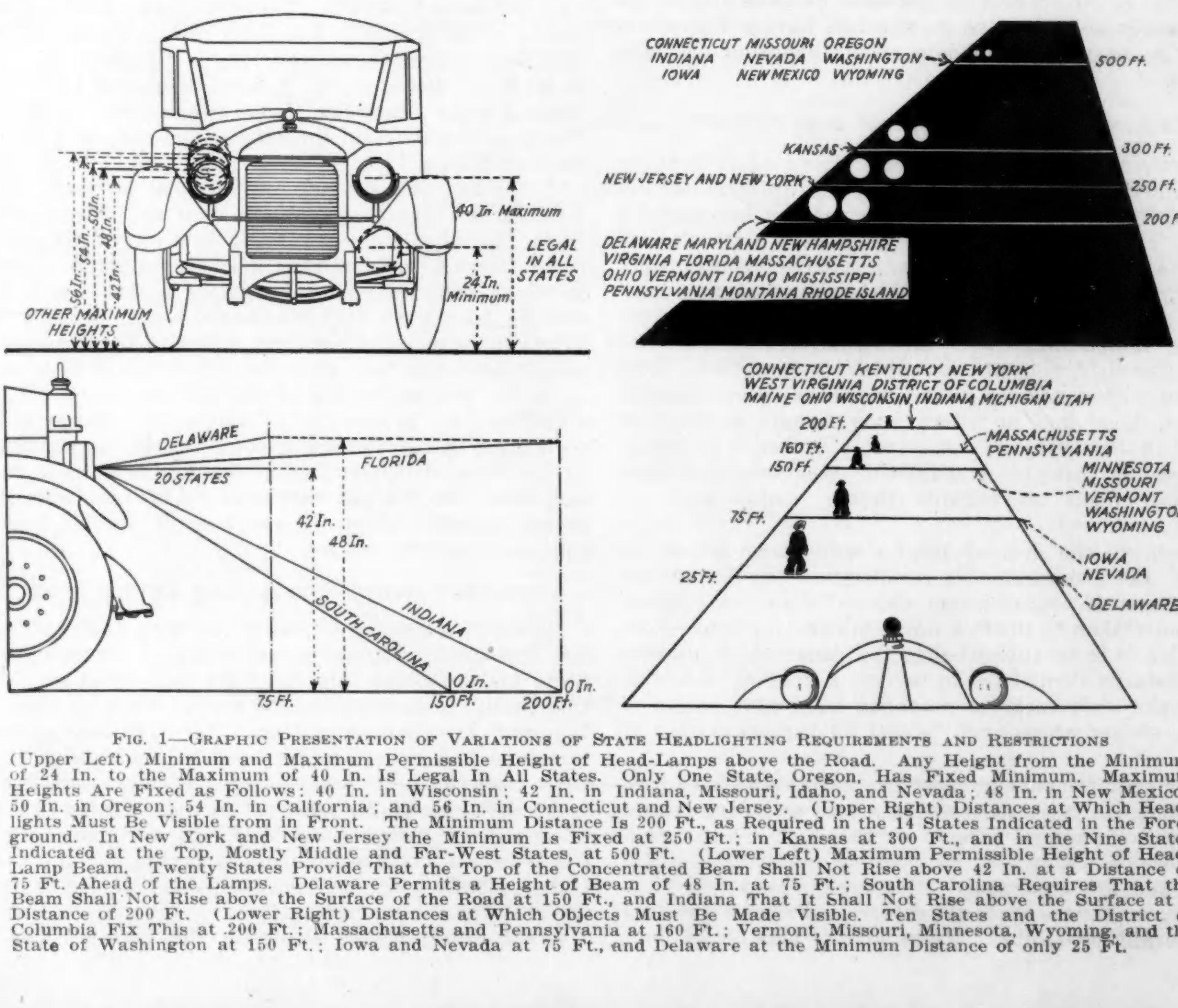

FIG. 1—GRAPHIC PRESENTATION OF VARIATIONS OF STATE HEADLIGHTING REQUIREMENTS AND RESTRICTIONS
(Upper Left) Minimum and Maximum Permissible Height of Head-Lamps above the Road. Any Height from the Minimum of 24 In. to the Maximum of 40 In. Is Legal In All States. Only One State, Oregon, Has Fixed Minimum. Maximum Heights Are Fixed as Follows: 40 In. in Wisconsin; 42 In. in Indiana, Missouri, Idaho, and Nevada; 48 In. in New Mexico; 50 In. in Oregon; 54 In. in California; and 56 In. in Connecticut and New Jersey. (Upper Right) Distances at Which Headlights Must Be Visible from in Front. The Minimum Distance Is 200 Ft., as Required in the 14 States Indicated in the Foreground. In New York and New Jersey the Minimum Is Fixed at 250 Ft.; in Kansas at 300 Ft., and in the Nine States Indicated at the Top, Mostly Middle and Far-West States, at 500 Ft. (Lower Left) Maximum Permissible Height of Head-Lamp Beam. Twenty States Provide That the Top of the Concentrated Beam Shall Not Rise above 42 In. at a Distance of 75 Ft. Ahead of the Lamps. Delaware Permits a Height of Beam of 48 In. at 75 Ft.; South Carolina Requires That the Beam Shall Not Rise above the Surface of the Road at 150 Ft., and Indiana That It Shall Not Rise above the Surface at a Distance of 200 Ft. (Lower Right) Distances at Which Objects Must Be Made Visible. Ten States and the District of Columbia Fix This at 200 Ft.; Massachusetts and Pennsylvania at 160 Ft.; Vermont, Missouri, Minnesota, Wyoming, and the State of Washington at 150 Ft.; Iowa and Nevada at 75 Ft., and Delaware at the Minimum Distance of only 25 Ft.

with two sets of brakes operated by independent means. In no case, however, is the language sufficiently definite to avoid controversies. Prior to the development of four-wheel brakes, virtually all motor-vehicles had two entirely independent brake systems, usually operated one by a pedal and the other by a hand-lever. Although usually separate and independent, in some cases both sets operated on the same rear-wheel brake-drums. But with the advent of four-wheel brakes, a number of makes of car have appeared that have only one set of brakes operating in all four wheels but provided with two independently operating controls, the pedal actuating all four brakes and the hand-lever the rear-wheel brakes only.

It has been contended by some that this latter equipment does not satisfy the requirements of the laws; while the proponents of this arrangement have stoutly maintained that the independent controls serve to provide all the required margin of safety on the parts most likely to fail. It is obvious, however, that if these brake laws are to be construed so liberally, a single brake on the driveshaft having both a hand and foot control would be regarded as legally satisfactory. Everyone knows, notwithstanding, that as ordinarily constructed such brakes, even though they might be capable of stopping the vehicle properly under test conditions, would have so little durability as to be most unsafe and in the event of the lining burning out would leave the vehicle incontrollable.

This is an interesting example of the way in which the normal commercial development of the motor-vehicle outdistances protective legislation in the real promotion of safety, as four-wheel brakes were developed quite independently of legislative inspiration, having indeed received no recognition to date at the hands of the lawmakers.

Seeking To Unify Braking Requirements

An attempt has been made recently to unify braking requirements in the State laws. The uniform vehicle code drafted by the Hoover Conference has incorporated general requirements which seem to meet with the approval of all the manufacturers. These requirements are shown in Fig. 3. Motor-vehicle commissioners have shown a tendency recently to interpret the laws as requiring vehicle brakes to accomplish certain definite results; namely, to stop the vehicle from certain rates of speed within definite distances. These requirements, however, have had no effect upon design, since most brakes on new vehicles are capable of bettering these requirements, but the requirements seem likely to have beneficial effects as regards proper maintenance of brakes.

To achieve the desired results without an excess of zeal by the commissioners resulting in too drastic activities, several organizations interested in the problem have undertaken to draft a uniform code for brake-testing which is to be submitted to the American Engineering Standards Committee to become a general standard. This brake code seeks to establish minimum limits of braking ability which must be met by various classes of vehicle.

Minor requirements in most of the laws seek to prevent obnoxious types of warning signal and particularly to prohibit the use of bells or sirens which are confused with those on public vehicles, such as ambulances, police patrols and fire apparatus. Stop signals and rear-view mirrors are in some cases obligatory, and muffler cut-outs are generally prohibited. From time to time speed governors are urged for obligatory equipment by well-meaning but poorly informed antispeed enthusiasts. So far these attempts have not been successful, but the possibility of laws requiring them is a constant menace. No type of governor has yet been developed that will limit in a practical way the speed of a passenger-car under all conditions and without restricting the proper performance of the vehicle. To be a complete safeguard, such a device would of necessity be actuated from one of the front wheels or part of the driving-mechanism and would be completely enclosed and sealed against tampering. If driven from the transmission, this would involve sealing the driving-gears to prevent a change of ratio, and also some means of preventing the installation of larger tires, which is obviously impracticable.

Motorcoach Development Hampered by Regulations

Motorcoaches have been subjected to the greatest amount of legislative restriction of any type of motor-vehicle. Motor-trucks have been affected seriously by limitations of size and weight but motorcoaches have suffered from similar restrictions and, in addition, in many States from exceedingly complicated and conflicting structural limitations which have seriously interfered with the interstate use of these vehicles and with standard construction of chassis, bodies and equipment.

Unfortunately, much of this regulation has been in the form of legislation so that modification in view of developments is rendered difficult and tedious. Six States permit a gross weight of vehicle and load of 28,000 lb., whereas two States have the maximum limitation as low as 15,000 lb. Three States permit an over-all length of 40 ft., while two limit the maximum to 28 ft. Total-width limitations vary from 102 in. in one State to 84 in. in two others. A total height of 13 ft. is allowed in one State but three others limit it to 12 ft. The length and width limitations are indicated for each State in Fig. 4.

A further dimensional complication is found in the New Jersey regulations, which limit the body length to 24 ft. This has a direct bearing on a recent development in motorcoach construction that contemplates a vehicle in which the powerplant is housed within the body so that the body itself occupies the full length of the vehicle. This can be made to conform with the 28-ft. maximum-length limitation but, with the restriction of body length to 24 ft., the realization of the advantages of this construction is prevented. Fortunately, however, the restriction in New Jersey is contained in the regulations by the Public Utilities Commission and is not a hard and fast law; the discretionary powers of the Commission permit special rulings in the case of special types of equipment of this nature.

Emergency Doors, Signals and Brakes Affected

However, a marked tendency has been observed in the last 3 years for regulations of this sort enforced in one State to be written into the fixed laws of other States. One of the most troublesome requirements is that pertaining to the emergency door. The experience of manufacturers and operators has resulted in general agreement that the best location for the emergency door is on the left side of the rear, yet in three States this type of emergency door has not been legal for some time and it has been necessary for manufacturers to build special types of body with the emergency door at the center of the rear for use in these States.

Great disagreement exists in the various laws and

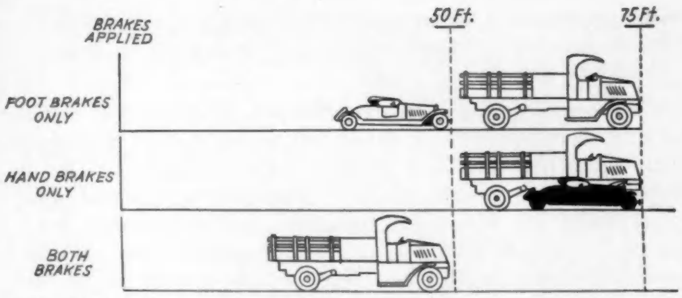

FIG. 3—BRAKING REQUIREMENTS OF PROPOSED SAFETY CODE FOR BRAKE AND BRAKE-TESTING

The Code Prepared for Submission to and Approval by the American Engineering Standards Committee as a Standard To Be Urged for Adoption by All States Provides That from a Speed of 20 M.P.H. the Foot Brakes Alone Shall Stop a Passenger-Car within 50 Ft. and a Motor-Truck within 75 Ft.; That the Hand Brake Alone Shall Stop Either Passenger-Car or Truck within 75 Ft.; and That Both Foot and Hand Brakes Shall Stop a Truck within 50 Ft. after Application of the Brakes

regulations concerning the location, arrangement, number, and color of marker-lights. Three States require a yellow stop-light notwithstanding all other States either ignore its color or require red. Braking requirements in some States, while somewhat ambiguous, seem definitely to bar a popular arrangement of four-wheel brakes wherein the pedal actuates all four brakes, the hand-lever acting on the rear-wheel brakes only.

The outlook on motorcoach regulation in general is hopeful, however, as is made evident by recent modifications of many of the more troublesome requirements in the older New Jersey regulations after consultations with representatives of the manufacturers, which were conducted under the auspices of the Society of Automotive Engineers, and after careful consideration of their criticisms and suggestions. A public hearing was held at which all of the moot questions were discussed and general agreement upon them reached. This is significant in view of the fact that the State of New Jersey has been the leader in motorcoach regulation whose example carries considerable weight with other States.

All motorcoach manufacturers are obliged to give careful consideration to legislation in the various States in all of their design work and in the selection of equipment for the vehicles. Lack of coherent uniformity has acted as a severe handicap on design development, for not only do the present statutes and regulations discourage development and enterprise along new lines, but the threat of further adverse action is a deterrent even where the way seems clear. Indeed, to be competent to design a motorcoach today, a man needs not only to be a peculiarly resourceful engineer, but also needs to be something of a lawyer, perhaps even a lobbyist.

HEAVY TRUCKS MOST SERIOUSLY AFFECTED

While regulation of motorcoach construction has presented a constant difficulty, specifically as it affects those details of design which determine the extent to which bodies and equipment may be standardized, the restrictive legislation on motor-truck design and operation has had a more specialized and profound effect upon the very economic fundamentals of transportation by truck. Undoubtedly the greatest effect of these laws has been to discourage the building of the most economical types of

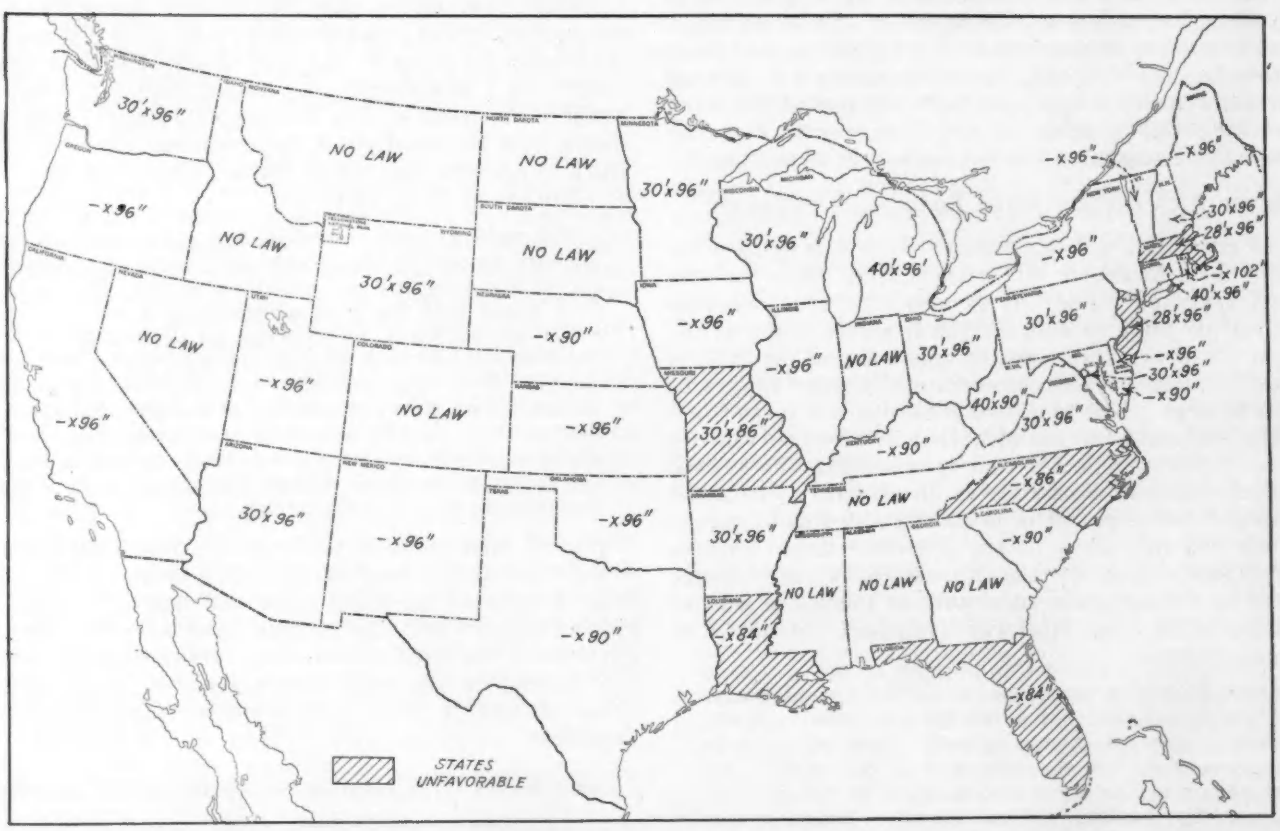

FIG. 4—MAXIMUM LENGTH AND WIDTH OF VEHICLES PERMITTED IN THE DIFFERENT STATES

The First Figure in Each State Is the Over-All Length of Single Vehicles in Feet, and the Second Figure the Over-All Width of Body and Load in Inches Allowed by State Law. Where a Dash Takes the Place of the First Figure, the Law Does Not Limit the Length of a Single Vehicle. For a Combination of Vehicles an Over-All Length of 60 Ft. Is Allowed in Michigan, West Virginia and Missouri; of 65 Ft. in Illinois, and of 85 Ft. in New Hampshire, Rhode Island, New Jersey, Virginia, District of Columbia, Pennsylvania, Ohio, Minnesota, Wyoming, and the State of Washington. The Shortest Permissible Maximum Length of a Single Vehicle Is 28 Ft. in Massachusetts and New Jersey; and the Narrowest Permissible Width of Body and Load Is 84 In. in Florida and Louisiana, and 86 In. in North Carolina and Missouri. The Last Six States Are Shaded To Indicate Unfavorable Size Limitations

transport vehicle; namely, large-capacity heavy-duty trucks.

The States almost universally today impose definite restrictions on this type, in the form of limitations of gross weight, vehicle weight, or carrying capacity. In addition, almost all States grant discretionary powers to the State highway departments for local jurisdiction to reduce the State-wide limitations with respect to certain types of road or at certain seasons of the year. These discretionary powers usually are exercised during the spring, when the highway sub-grades have become softened due to the thawing of frost in the ground.

State regulations regarding speed, lighting equipment, total width, and height are not troublesome as a rule. The regulation of gross weight in one form or another has had the most drastic effects upon motor-truck design and operation.

The weight-limitation situation arises from the desire of public officials to prevent rapid destruction of highways by operation over them of vehicles for which the highways are unsuited. The general impression prevails that a vehicle is destructive of a highway in proportion to its weight, although most States give some consideration to the relative concentration of this weight by limiting the weight per inch of tire width, or the weight per axle, and, in several cases, by allowing additional gross-weight to be carried if it is divided among more than two axles.

Moreover, it seems to have been the belief that by limiting the gross weight that may be imposed upon the highway, enforcing such limitations by stringent check-up with scales and loadometers and the imposition of heavy fines for violations, operators of trucks would be forced to confine themselves to light vehicles and loads and that the roads would thereby be preserved. Several important considerations have been overlooked, however, in reaching this conclusion, and the general economic effect of these measures has not been studied sufficiently.

Economics Involve Both Roads and Vehicles

It is true that a great many roads throughout the Country are incapable of withstanding any but the lightest types of traffic. It is also true that, whereas roads can be built to support the heaviest types of vehicle in operation, their cost of construction per mile is so great as to render them economic only when the traffic volume is large. The principal difficulty lies in the fact that the economics of the situation involve the vehicles and the highway together and inseparably. To regard prevailing highway capacities as an arbitrary limitation on transport development is as short-sighted as to regard costs per ton-mile alone as the economic test. Thomas H. McDonald, chief of the Bureau of Public Roads, summed up the situation admirably as follows in a brief submitted to the Joint Highway Transport Committee at Chicago recently:

> The building of an adequate mileage of highways is a continuous but not a quickly completed process. For many years highways already improved must be held in service, but the existence of obsolescent sections should not be given consideration in fixing specifications for loading. Administrative measures for reconditioning and reconstruction should be such as to provide for rebuilding when maintenance indicates the necessity for such measures.

In the same report, he also says:

> The movement of motor-trucks is determined by economic laws. It should not, and cannot successfully, be interfered with by regulation, within a system of highways of so nearly equal importance as a State highway system.

The present laws affecting motor-trucks are based largely on assumptions, many of which are at variance with scientific fact and economic common-sense. As a result of more than 8 years of continuous research and experiment by the most qualified authorities on both highway construction and transport engineering, it has been definitely established that gross weight is by no means a fair measure of the road-destructive potentialities of the vehicle. It has been demonstrated clearly by no less a body than the Bureau of Public Roads of the Department of Agriculture that static weight has no harmful effect upon properly constructed roads. This does not by any means confine the application of this statement to the best of improved highways.

Major Factors That Cause Road Destruction

It has been established that the destructive agent is the impact on the road and that impact is governed by other factors than weight alone. Speed, tire equipment, suspension, and character of road surface are all major influences. This is borne out by a report made by the Bureau of Public Roads in June, 1926, in which the factors affecting road impact are summarized as follows:

> The impact road-reaction of a motor-truck depends in general upon the four major variables: wheel load, truck speed, tire equipment and road roughness, or height of obstruction.

It has been shown that the relative sprung and unsprung weights of a vehicle make a marked difference in the impact delivered to the road under otherwise similar conditions. Regarding the importance of unsprung weight, the tests by the Bureau of Public Roads have shown that the reaction of the unsprung portions of the truck constitute the major impact shocks on the road, as reported in June, 1926:

> The vertical impact-reaction, separated into its components, caused by the sprung and unsprung parts, is shown for a typical test condition in Fig. 27. It has been found that the most severe impacts are obtained either at the shock on striking an obstruction or at the first rebound or drop after the obstruction has been passed. It is also generally true that the unsprung component of the road reaction is the major quantity, and, so long as the unsprung truck-weight is decelerated or accelerated at all, it is likely to be the deciding factor in the total road-reaction, regardless of the compression of the truck spring.

Fig. 27 referred to in this report is reproduced in Fig. 5 herewith. It has been shown that a truck even of moderate weight at excessive speed and having a large unsprung weight, stiff springs and tires worn thin or with portions of the tread missing may produce more destructive impact on the road than a truck of much greater gross weight in which these other factors are more favorable.

Laws Make Overloading Economically Necessary

Restrictions on gross weight have been set arbitrarily in some States just below that which would admit types of vehicle that are best adapted economically to certain classes of service. In other cases the maximum weights allowed are so low that nothing but the lighter delivery types of chassis can be used legally. One great defect in most of the weight laws is that no adequate provision

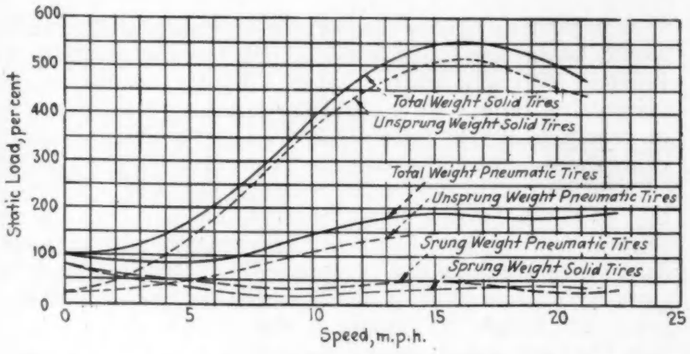

FIG. 5—RELATION OF VERTICAL IMPACT-REACTION TO TRUCK SPEED
At a Speed of 15 to 17 M.P.H. the Impact Reaction with Solid Tires, Loaded to Rated Capacity on a 2-Ton Truck, Resulting from a 1½-In. Drop from a 30-in. Inclined Plane, Is 4½ Times Greater than the Static Load, and That of the Unsprung Weight Is More than 4 Times the Static Load. At the Same Speed the Impact Reaction with Pneumatic Tires Is Less than Double the Static Load. At 20 M.P.H. the Reaction of the Sprung Weight Is Less with Solid than with Pneumatic Tires, and That of Both Is Less than at a Speed of 5 M.P.H. or Less

is made to guard against overloading. The result has been that, with the limited gross-weight allowance, users have been encouraged to purchase unduly light types of chassis so that large payloads might be carried without exceeding the gross-weight allowance.

Such practice is not only uneconomic from the operating viewpoint but it is entirely within the range of possibility that such grossly overloaded vehicles are actually more destructive of the highways than are heavier chassis properly adapted to the loads imposed upon them. It has been said that some of these gross-weight laws, such as the Burks law in Ohio, are, in effect, compulsory overloading laws. This phase of the subject has been so completely ignored in New York State that it is actually possible to license a 1-ton Ford truck for a gross weight of 28,000 lb.

Among the economic factors that have been overlooked is the important one that heavy trucks of the types which are the particular target of the legislators do not traverse State highways but are operated chiefly in cities, where in many cases the street pavements are of such nature that the vehicles can have no destructive effect. This confined use of heavy trucks arises from the fact that large loads for single trips are available usually only close to large markets. In the more populous portions of the Country trucks of heavy types are also used, to be sure, for so-called long-distance intercity transportation, in which service they do traverse main traveled State roads. In these cases, however, they are engaged in work of great economic value and their operation is confined to a relatively small proportion of the State road-system. Furthermore, such portions of the State road-systems usually are provided with the heaviest types of pavement, made necessary by the large volume of all kinds of traffic which they must sustain. No occasion arises, as a rule, for truck operators to run the heavier types of truck into the districts where highways of light type prevail.

NEED STUDIES OF AGGREGATE WEIGHT TRANSPORTED

A feeling seems to exist that the economies effected by the larger capacities of motor-truck benefit the operators of the trucks alone and that the public has no interest in fostering economical highway-transport; yet anyone who has even the slightest familiarity with the simplest phases of economics must realize that, in the play of free competitive influences, increasing the efficiency and economy of any common line of endeavor operates to increase production and lower prices and therefore is of benefit to everyone. In endeavoring to limit unit loads by restricting weight, the legislators have overlooked the fact that such action cannot materially affect the total amount of goods transported over a given road but that the effect is to require a greater number of vehicles to transport the same quantity of goods and that, in the aggregate, this greater number of vehicles will represent a greater tare weight, increase traffic congestion and impose a burden of added transport cost for which no corresponding gain will be realized.

The Bureau of Public Roads has contributed some valuable data on this subject as a result of traffic counts in Connecticut and Cook County, Ill. These counts showed that in Connecticut 11.7 per cent of the total truck-traffic consisted of trucks of 5-tons capacity and more, and in Cook County, 9.8 per cent. Expressed in tonnage, this would amount to 34.0 per cent in Connecticut and 27.5 per cent in Cook County. More of this sort of traffic studies is needed to determine the amount of traffic accommodated by trunk highways, the value of such traffic and the most appropriate type of vehicle to be used. Some interesting results from these studies are shown in Table 1. From such a study it should not be difficult to arrive at the economic gain to be realized from the use of heavy vehicles and to balance this gain against the comparative cost of light-service versus heavy-service roadways.

A start has already been made in classifying roads by their sustaining capacity. This principle might be extended to give a State Highway Commission authority to establish certain classifications of highway and designate the carrying capacity of each classification in conformance with a classification of trucks by the motor-vehicle registration bureau. Thus, a Class 4 truck, which might be any having a gross weight of 10,000 lb. or less, would be permitted to operate over any type of road at any time; a Class 3 truck, of 18,000 lb. or less, might operate on roads of Classes 1, 2 and 3; a Class 2 truck, of a gross weight up to 24,000 lb., could be used on a Class 1 or 2 road; and a Class 1 truck, up to 30,000 lb., might operate only on a Class 1 road. Bridges should, naturally, have a safe capacity equal to that of the roads of which they form a part.

The economic significance of motor-truck load-capacity is far too little understood generally. An impression seems to prevail among certain classes that, without legislative restraint, truck manufacturers would leave the best products of the highway engineer's skill in ruins. Some persons believe that the heaviest types of truck are built and sold only for special classes of service, that relatively few operators can make use of

TABLE 1—TRUCK TRAFFIC AND TONNAGE IN CONNECTICUT AND COOK COUNTY, ILL., BY PERCENTAGES OF VEHICLES OF DIFFERENT CAPACITIES

Rated Capacity, Tons	Truck Traffic, Per Cent of Total: Connecticut, Chassis	Connecticut, Tonnage[3]	Cook County, Ill., Chassis	Cook County, Ill., Tonnage[3]
½ to 1½	65.8	38.0	57.6	31.0
2 to 2½	13.4	15.0	20.1	21.5
3 to 4	9.1	15.0	12.5	20.0
5 to 5½	10.6	30.0	8.6	23.0
6 to 7½	1.1	4.0	1.2	4.5

[3] Computed on the basis of average rated capacity of the chassis; not a part of the official report of the Bureau of Public Roads.

trucks of such capacity, and that to tax or regulate them out of existence would create only a minor hardship.

Large Unit-Loads Are More Economical

The fact is that motor-trucks are not becoming larger and heavier but that capacity requirements have become fairly well standardized in the last 15 years. In the earlier stages of motor-truck development, trucks of as much as 20-tons capacity were built, and for a number of years 10-ton trucks were in active production. It does not require the weight of authority or long mathematical demonstrations to prove that the truck of 5 to 7½-tons capacity, when properly applied, is capable of handling loads at a lower cost per ton-mile than trucks of smaller capacity. Two 2½-ton trucks cannot possibly transport the same amount of load as economically as one 5-ton truck. The investment in the two smaller trucks is greater, they will burn more fuel in doing the same work, wear out more rubber, cost more for repairs, occasion double the labor charge, require nearly twice the garage space and loading platform and traffic room, and in usual traffic conditions will be capable of little if any greater speed than the larger truck.

The principle of handling freight in large units, up to certain practical limits, is well established and universal. The development of transportation by rail has been steadily in the direction of larger freight cars, longer trains and more powerful locomotives, and the railroads have found it economically expedient to provide heavier roadbeds, stronger bridges and larger rails to support the greater train-weights. In marine transport, ships of excessive tonnage have been built and a reaction from the extreme in this direction has occurred but the general trend is toward greater average displacement in freight bottoms.

Of all motor-trucks and commercial cars registered in the United States today, 4¾ per cent are of 5-tons capacity and more. This figure is the basis of the popular idea that the large-capacity truck is a negligible factor. However, two facts should be borne in mind: (*a*) these large-capacity trucks are used principally in and around the large centers of population and (*b*) their significance in the general transport-scheme is more truly measured on a tonnage basis than by mere numbers of chassis represented. Assuming the average of all trucks of 5-tons capacity and upward to be 6 tons, it is seen from Fig. 6 that these represent more than 20 per cent of all of the truck tonnage in America. When it is further considered that they are used principally in the more populous portions of the Country, it will be seen that, despite the adverse influence of legislation that is antagonistic to large-capacity trucks, a very considerable part of the motor transport in the more thickly-settled States is dependent upon large-capacity trucks.

Small-Capacity Trucks Cause Large Losses

It is safe to assume that nearly 2,000,000 tons of freight is being transported daily in trucks of 5-tons capacity and more. The cost of this transportation may be estimated conservatively at not more than two-thirds of the cost that would be incurred if the same tonnage were transported in 3-ton trucks. It is impossible to estimate exactly the average cost per ton for this prodigious volume of traffic, but at a conservative figure of 35 cents per ton, this represents a daily transport bill of $700,000. If this represents two-thirds of the cost of performing the same service with 3-ton trucks, the larger trucks are saving $350,000 per day, or $105,000,000 a year.

A great many more large-capacity trucks undoubtedly would be in use today were it not for the restrictions imposed by many of the States. Either through gross-weight limitations or prohibitive taxation, the operation of trucks of 5-tons capacity or more is prevented in 18 States and is discouraged in as many more. The cost of this to the public can hardly be guessed. The aggregate cost of virtually compulsory overloading in this group of States in the way of excess maintenance and extreme damage to roads is also a matter for conjecture, but a cursory consideration of available figures cannot but impress the thoughtful student of the subject with the fact that the tremendous economies which might be and are realized by encouraging the more efficient transport of freight by the larger sizes of truck would go a long way toward providing the sort of roads necessary for such types of truck on the comparatively limited mileage of roads which they would normally traverse.

Automotive engineers are ready to provide the truck designs and manufacturers are prepared to furnish the materials, facilities and capital to produce these economic vehicles. It remains only for the legislators to open the way to normal economic evolution. If those prevail who seek unwisely, but no doubt sincerely, to preserve the roads as they are, regardless of what they should be and of the economic handicap thus placed upon motor transport, the automotive industry will be obliged to develop along other lines less economic than the ideal, yet more economic than the present orgy of overloading which is so characteristic of certain phases of motor transport in many localities.

New Developments Forced by Restrictions

Weight limitations already have had a profound influence upon motor-truck construction in the drafting rooms of the industry. A new meaning has been given to such terms as factor of safety, performance and even the definition of the term "ton." As the stringency of weight limitations and their enforcement has increased, abuse of motor-trucks, particularly overloading, has become aggravated. To protect the good name of their product, engineers have been obliged continuously to increase the factors of safety, and as a result structural weights and the cost of construction have increased. Users, faced with drastic limitations on the weight of load that can be carried per trip, have striven desperately to speed-up their operations to make more trips and haul the same tonnage in smaller loads in a given time. This has brought new demands upon the manufacturers for quicker acceleration, higher sustained-speed, better hill-climbing, and better brakes, notwithstanding all of these mean higher costs.

Motor-truck interests in several of the States, after failing to persuade the legislators to increase the weight limits, have been successful in getting through special concessions for multiple-axle types, such as the tractor-semi-trailer combinations and six-wheel vehicles. The weight limitations of all the States and the additional gross weight allowed in some States when three or more axles are used are given on the map, reproduced as Fig. 7. These additional allowances have given great impetus to the development of multiple-axle types of vehicle. Not all of the States have as yet recognized the benefits of six-wheel vehicles; 25 States and the District of Columbia do not permit additional weight to be carried on three axles, and Arkansas and Nevada stipulate that the axles must be 96 in. or more apart for any additional allowance. This situation is summarized in a report

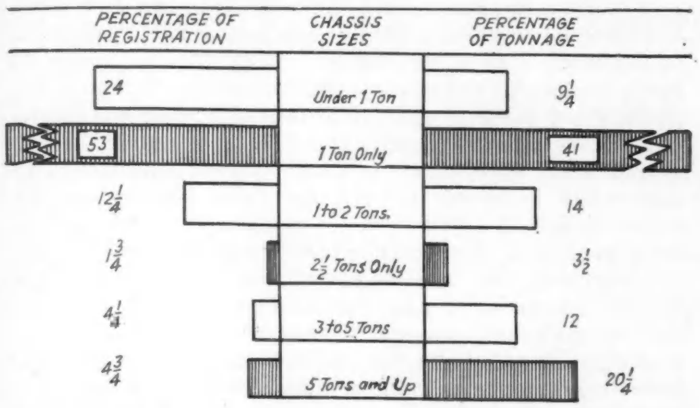

FIG. 6—PERCENTAGES OF TRUCKS OF DIFFERENT CAPACITIES REGISTERED IN THE UNITED STATES AND OF THEIR AGGREGATE TONNAGE CAPACITIES

Although Trucks of 1-Ton Capacity Represent 53 Per Cent of All Trucks Registered, They Have a Combined Load-Capacity of Only 41 Per Cent, Whereas Trucks of 5-Tons Capacity and More Represent only 4¾ Per Cent of All Registrations but Have a Combined Tonnage Capacity of 20¼ Per Cent. Therefore, While the Latter Sizes Seem Rather Negligible as Regards Number, They Constitute the Second Most-Important Group in Volume of Tonnage

made by the Bureau of Public Roads in October, 1925, as follows:

> The six-wheel truck is the motor-vehicle designers' solution of the problem presented by the demand for vehicles which will carry heavy pay-loads without violation of the restrictive regulations adopted for the protection of the highways. Facing such restrictions, the motor-vehicle designers have sought to increase the legal carrying-capacity of the single vehicles by using four wheels instead of two at the rear, where the bulk of the load is carried, thus doubling the number of axles, wheels and inches of tire width by which the load is transmitted to the pavement.

From this introduction, the report continues with a detailed account of the careful, scientific tests by which the effects of such equipment on road stresses and impact values were definitely determined. These tests showed conclusively that for the same load carried, the six-wheel truck imposed smaller stresses on the road than the four-wheel type and, perhaps most significantly, that the spacing of the rear axles, from the practical minimum of 36 in. upward, makes no difference. The conclusion on this point reads:

> In the case of six-wheel vehicles the maximum tension produced in the pavement seems to be a function of the wheel load and not of the axle spacing, at least between the limits of 3 and 10 ft.

Reinforced by the findings of the Bureau of Public Roads with respect to the lower impact delivered by pneumatic tires as compared with solid tires on the same vehicle, earnest workers have been successful in inducing several of the legislatures to approve greater gross-weights, or at least smaller license fees, on pneumatic-tire trucks. This in turn has led to a steady increase in pneumatic-tire equipment on the heavier-capacity vehicles.

Each of these developments has been productive of much good, not only in alleviating acute hardships of the moment, but in enlarging the sphere and potentialities of motor-vehicles. But it should be borne in mind that none of these developments is a substitute for the 7½-ton four-wheel solid-tire truck, which still has and always will have a legitimate place in motor transport, a right earned by its demonstrated efficiency and economy. The six-wheel and pneumatic-tire trucks are undoubtedly permanent developments and will carve out a particular

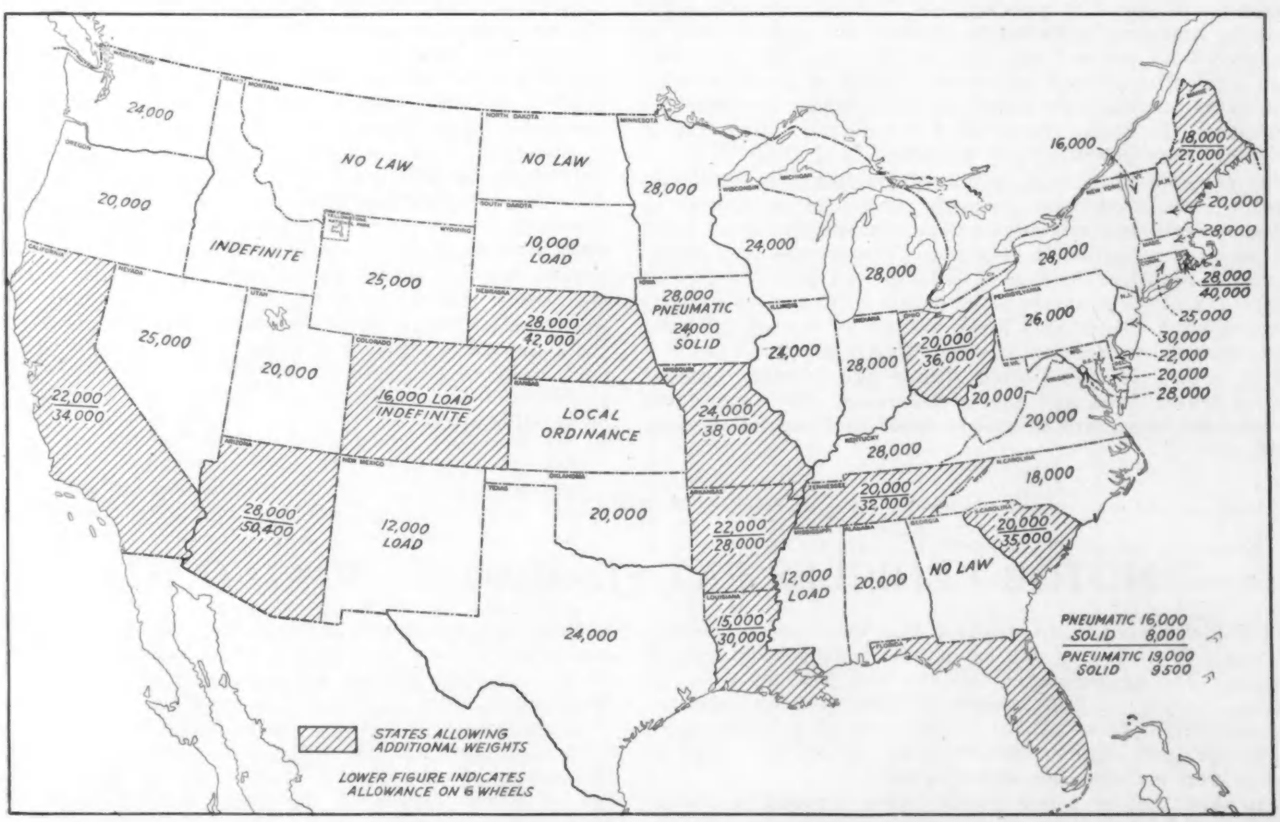

FIG. 7—MAXIMUM VEHICLE WEIGHTS ALLOWED IN THE DIFFERENT STATES

In the States Where Only One Figure Is Shown, the Figure Is the Allowable Gross Weight of the Vehicle and Load in Pounds, or of Load Only, as Specified in Mississippi, North Dakota and New Mexico. The Shaded States Permit the Larger Gross Weight Shown in the Lower Figures To Be Carried on Six Wheels, or Double the Weight To Be Carried on Pneumatic Tires, as in Florida

niche for themselves in conformance with the immutable laws of economics, in the same way that the tractor and trailer have done, but they are not and can never be substitutes for the 7½-ton solid-tire truck.

Solution of Problem Requires Engineers' Aid

Often in discussions of the effects of legislation on automotive design, wherein manufacturers discover themselves obliged to turn their attention to the production of greater numbers of lighter units to take the place of proscribed heavy units, the philosophy is advanced that the manufacturer really has no concern in the controversy; that he can make as much profit from the sale of many light vehicles as from a lesser number of heavy ones; that the general public is the loser; and that it is the general public's battle. Such arguments would be good from the manufacturer's viewpoint if the public were obliged in all cases to use motor transport regardless of its efficiency, but it should be readily apparent that, if the misguided zeal of short-sighted and uninformed legislators is allowed to militate too greatly against economic highway-transport, much of the traffic that should, and normally would, fall to automotive vehicles for transportation will revert to the older forms of transportation. What the automotive industry needs is less legislation in engineering and more engineering in legislation.

What can the automotive engineer do to mitigate some of the evils which may result from unfavorable extension of legislation affecting motor transport? He must do much to assist the industry with which he is associated in adapting itself to the continually changing conditions created by legislative activity. There is much that he should do in addition. The world looks to engineers and economists to bring to light the facts bearing on the situation and to bring to bear on these facts the practical reasoned analysis and interpretation for which the real engineer, who must be something of an economist, is trained. Legislative and regulatory bodies are learning the necessity and benefits of coordinated action. They welcome, even solicit, the advice and cooperation of trained engineers in solving their problems. The lawmakers have not always acted wisely, but theirs has not been an easy task, and the technical assistance which their problems demand has not always been readily forthcoming.

A dozen or more organizations in this Country are striving to bring the light of fact and reason to bear upon the problems of motor-vehicle regulation. These bodies are representative and demand the efforts of earnest, unselfish and enlightened workers. They cannot carry the load alone; they require the cooperation and assistance of individuals such as make up the membership of the Society of Automotive Engineers.

MASS PRODUCTION AND HIGH WAGES

In American agriculture, product per acre is low as compared with product per acre in Europe. On the other hand, in American agriculture, product per man is high as compared with product per man in Europe. Europe cultivates agricultural land intensively, using a great number of laborers on relatively small pieces of land. In American agriculture we utilize farm labor intensively, spreading it out thinly over our relatively abundant land.

The same thing is true in manufacturing. We excel Europe in mass production. Europe excels us in specialties and manufacturing activities where considerable hand labor and personal attention is required. The volume of successful mass production in Europe is large and with the growth of capital and the progress of invention will increase greatly. In the United States this large volume of successful hand production and production of specialties is also the case.

High wages in the United States are possible because labor is scarce, land and capital abundant, and the product per man working with abundant labor and capital is high. Wages come out of product. They tend to equal the product that can be specifically assigned to the marginal laborer. If the marginal product of labor is high, owing to the scarcity of labor, wages tend to be high. If labor is so abundant that the marginal product of labor is low, wages tend to be low. Wages on the American scale cannot be introduced into Europe because the product out of which to pay them does not exist. Similarly, mass production on the American scale cannot be transferred to Europe. The natural resources and the capital are not available. The European employer who undertook American methods of mass production, employing a small number of laborers with a vast aggregation of capital and land, would find himself defeated in the European markets by competitors who met the situation more naturally, using the abundant labor at their disposal to perform many of the operations that he performed with relatively expensive machinery and high priced land and natural resources.—B. M. Anderson, Chase National Bank.

MOTOR-VEHICLES PAY $1,000,000,000 ROAD COSTS

Motor-vehicle drivers last year paid taxes, averaging 2.38 cents per gal., on almost 8,000,000,000 gal. of gasoline. The aggregate of this tax was $187,603,231. In addition, they paid $288,282,352 in motor-vehicle registration and license fees. About 95 per cent of gasoline taxes and 93 per cent of motor-vehicle registration fees went to building and maintenance of highways.

If to this total be added special taxes imposed on motor-coaches and motor-trucks, property taxes on motor-vehicles, the taxes paid by the petroleum industry and the motor-vehicle manufacturers, a total above $1,200,000,000 is reached. That is, the people who buy, operate and manufacture motor-vehicles and produce, buy and burn gasoline are considerably more than paying the Nation's good-roads bill, which now runs, according to the Federal Bureau of Public Roads, just about $1,000,000,000 annually.

Gasoline taxes are now assessed in 45 States and the District of Columbia. The only States which do not impose this tax are Massachusetts, New York and Illinois. A number of States increased the gasoline tax within the last year, but none reduced it. The tax ranges from 1 cent per gal. in Rhode Island and Texas, to 4 cents in Arkansas, Florida, Nevada and North Carolina; 4½ cents in Washington; and 5 cents in Kentucky and South Carolina.

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The Quantitative Effect of Engine Carbon on Detonation

By Neil MacCoull[1] and D. B. Brooks[2]

Buffalo Section Paper *Illustrated with* Charts

ABSTRACT

METHODS adopted and results obtained in an investigation of the quantitative effect of engine carbon on detonation are described, together with the standard methods of detonation and carbon-deposition measurement that were used. It is stated that carbon deposition is believed to influence detonation in proportion to the greatest thickness of deposit over any considerable area of the combustion-chamber surface. Since this is indicated, it is suggested that detonation tests should supersede gravi-metric carbon-deposition tests, inasmuch as the objection to carbon is because of its detonation-inducing characteristics, which are governed by the character and the thickness of the deposit.

The tests were made with a four-cylinder, model DU-8 Waukesha motor-truck engine of 4½-in. bore and 6¼-in. stroke, direct coupled to a Sprague Electric dynamometer. A crankcase jacket enabled control of the oil temperature. The temperature of the jacket under water at the inlet was maintained at 100 deg. fahr. and that of the carbureter air at 200 deg. fahr. A mercury barometer was attached to the intake-manifold for indicating absolute intake-manifold pressure. For antiknock tests, the engine was provided with high-compression cylinder-heads and was operated at a speed of 400 r.p.m. The throttle was opened gradually and the load was increased simultaneously until a point was reached at which a certain definite standard amount of detonation occurred. The absolute intake-manifold pressure was then recorded. A calibration was then made by using a standard fuel and observing the manifold pressure at which it detonated.

Standard fuels were prepared by adding various quantities of "ethyl fluid" to Texaco spirits, the latter being a cut distilling at a temperature of from 300 to 425 deg. fahr. The carbon-deposit results, excepting the carbon-remover tests, were obtained in the course of routine antiknock test-work; that is, the deposit was allowed to accumulate for a period while routine tests were being made. Hence the deposit was formed under non-uniform conditions as regards fuel and load.

To measure the effect of the carbon on various parts of the combustion-chamber surfaces of the engine in increasing detonation, the engine was operated for about 40 hr. under the standard conditions. It was then dismantled and the deposit was scraped from the cylinder-head only, leaving the cylinder-block, the valves and the pistons with a considerable depth of carbon. The engine was then reassembled and operated, with frequent calibrations, for another period of about 40 hr. Later, the same procedure was used, scraping the cylinder-block, the valves and the pistons, instead of scraping the cylinder-head.

A test was made of a popular carbon remover, not on the basis of the comparative weight of the carbon deposit but on the basis of the comparative detonation-inducing tendency of the deposit. Fresh oil was added every 15 min. The engine was equipped with a Stromberg carbureter having a No. 57 orifice but no needle-valve or idling-jet.

Points brought out in the discussion relate to whether various amounts of carbon accumulation can be used to determine whether some one combustion-chamber is a better type than some other; the effect of turbulence; the effects of additions of nitro-benzene and of aniline; and the desirable characteristics of oils.

THE action of carbon deposit in an automotive engine in inducing detonation is well known in a general way. A car with a clean engine will climb a certain hill in high gear without knocking, but, after driving the car for 2000 to 3000 miles, it is necessary to retard the spark or drive in second gear to suppress the detonation on the same hill unless an antiknock fuel is used. The increasing attention which is centering of late on the subject of carbon deposition in automotive engines makes it of interest to know what the quantitative effect of carbon deposit on detonation is, and how it can be

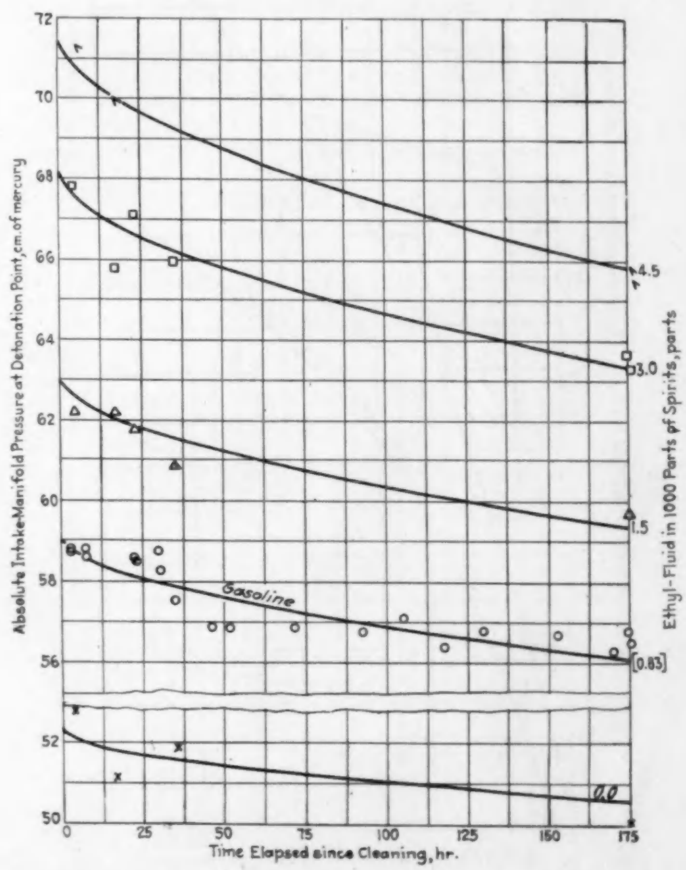

FIG. 1—TIME RATE OF DECREASE OF ABSOLUTE-INTAKE-MANIFOLD PRESSURE AT THE DETONATION POINT

These Curves Show the Falling Off of Manifold Pressure at the Detonation Point as Continued Operation Increases the Carbon Deposit

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measured. A method which has given reasonably consistent results is described in this paper, together with test results indicating that detonation is directly proportional to the carbon deposit. The data presented herein were by-products of a fuel-research program, and hence are not as well coordinated as might be desired.

Apparatus and Test Methods

The tests were made with a four-cylinder Waukesha Model DU-8 motor-truck engine of 4½-in. bore and 6¼-in. stroke, direct coupled to a Sprague Electric dynamometer. A crankcase jacket enabled control of the oil temperature; the jacket water at the inlet was maintained at 100 deg. fahr. and the temperature of the carbureter air was kept at 200 deg, fahr. A mercury barometer was attached to the intake-manifold, giving absolute intake-manifold pressure.

For antiknock work this engine was provided with high-compression cylinder-heads and operated at 400 r.p.m. The throttle was opened gradually and the load was increased simultaneously until a point was reached at which a certain definite standard amount of detonation occurred. The absolute intake-manifold pressure was then recorded. A calibration was then made by running with a standard fuel and observing the manifold pressure at which it detonated.

Standard fuels were prepared by adding various quantities of "ethyl-fluid" to Texaco spirits, the latter being a cut distilling at between 300 and 425 deg. fahr. The antiknock values hereinafter used, for example 1.5 ethyl-fluid, refer to the number of parts of ethyl-fluid per 1000 parts of Texaco spirits. Since these fuels are all almost entirely composed of spirits, they are metered identically by the carbureter; therefore, the question of the influence of air-fuel ratio does not enter into this work as it does when fuels of different gravity and viscosity are being tested for antiknock value.

The carbon-deposit results, except for the carbon-remover tests, were obtained in the course of routine antiknock test-work; that is, the deposit was allowed to accumulate for a period while routine tests were being made. Thus, the deposit was formed under non-uniform conditions as regards fuel and load. However, the individual tests lasted on the average about 10 min.; hence, the results after the long periods required in the deposition tests are fairly well averaged.

Increase of Detonation with Carbon[3]

Fig. 1 shows the results of calibrations with standard fuels at various times subsequent to scraping the carbon from all the combustion-chamber surfaces. In Fig. 1, the absolute intake-manifold pressure which gave the standard amount of detonation with each of five standard fuels is plotted against the number of hours of operation during which the carbon deposit had been accumulating. It is apparent that the manifold pressure at the detonation-point decreases rapidly during the first few hours, and less rapidly as time goes on.

[3] See The Journal, January, 1926, p. 48; see also The Journal, June, 1926, p. 607.

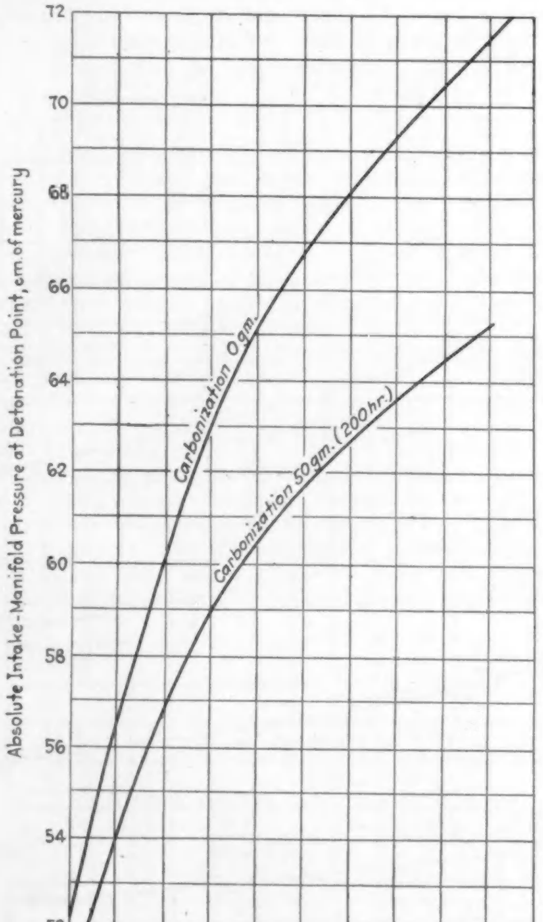


Fig. 2—Calibration Curves

The Curves Shown Were Faired from the Curves of Fig. 1. They Indicate More Clearly the Large Decrease in Manifold Pressure at the Detonation Point Caused by the Deposition of 50 Grams of Carbon

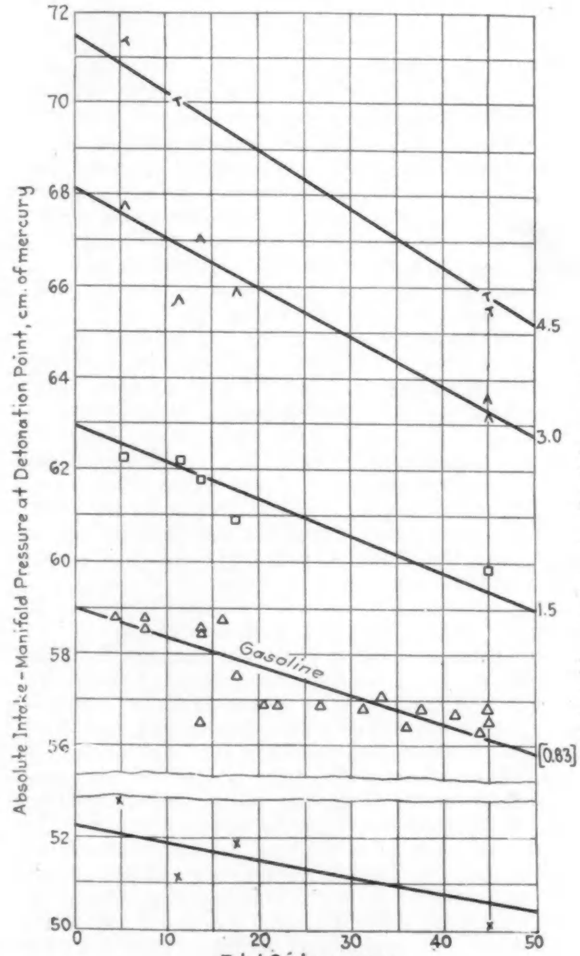


Fig. 3—Variation of Detonation Point with Weight of Carbon

The Chart Shows That the Decrease of Manifold Pressure at the Detonation Point is Directly Proportional to the Weight of Carbon Deposited

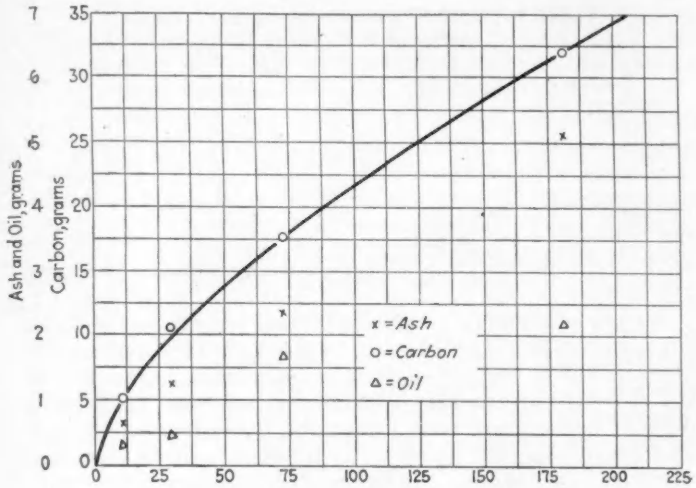


FIG. 4—TIME RATE OF FORMATION OF CARBON DEPOSIT ON THE CYLINDER-HEAD

A Single Equation, $y=1.09x^{0.65}$ Fits the Carbon Deposition Within the Limits of Observation

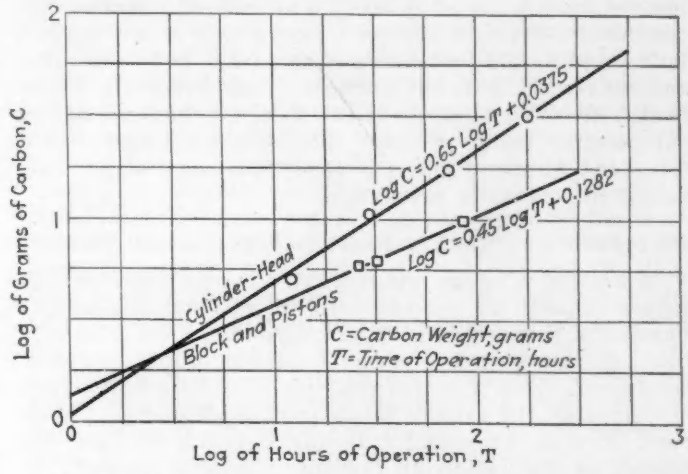


FIG. 5—CARBON FORMATION SHOWN ON LOGARITHMIC SCALE

Fig 4 Is Projected on a Logarithmic Scale as a Straight Line. Additional Data Are Given Showing the Rate of Deposition on the Cylinder-Block

The decrease in manifold pressure at the end of about 200 hr., due to carbon deposition, can be appreciated better from Fig. 2, in which the absolute manifold-pressure required to produce standard detonation is plotted against the antiknock value of the fuel used, for a perfectly clean engine-condition and also for the engine when fouled with a deposit of 50 grams of carbon.

The shape of the curves of Fig. 1 resembles those of carbon-deposition curves; that is, the decrease in manifold pressure with time suggests an exponential curve. Hence, it is not surprising to find that, when the absolute manifold-pressure for a given fuel is plotted against the weight of carbon deposit accumulated at that time, a straight-line curve is obtained as shown in Fig. 3.

If these curves were extended, they would converge at about 200 grams deposit and 45 cm. (17.72 in.) of mercury absolute-manifold pressure. This apparent anomaly is due in part to variation in air-fuel ratio at the different manifold pressures. In any case, an extrapolation to such an extent is not justified.

The data on carbon deposition which were used as a basis of Fig. 2 are shown in Figs. 4 and 5. In this work, all results have been based on deposition corrected for oil and ash; however, from the results shown in Fig. 4, it is believed that the data would be as well coordinated were they based on oil-free deposit, since the ash appears to be strictly proportional to the carbon.

RELATIVE EFFECT OF DEPOSIT ON VARIOUS PARTS

To measure the relative effect of the carbon on various parts of the engine combustion-chamber surfaces in increasing detonation, the engine was operated for about 40 hr. under the standard conditions. It was then dismantled, and the deposit was scraped from the cylinder-head only, leaving the cylinder-block, the valves and the pistons with a considerable deposit of carbon. The engine was then reassembled and operated, with frequent calibrations, for a period of about 40 hr. again. Later, the same procedure was used, scraping the cylinder-block, the valves and the pistons, instead of scraping the cylinder-head.

When compared with the curves of Fig. 3 these results were found to be uniformly lower, indicating that the carbon present in unequal thickness on cylinder-head and cylinder-block had greater effect per unit quantity on detonation than it had when present in approximately equal thickness on cylinder-head and cylinder-block. The results of these tests were therefore compared with the curves of Fig. 1, and were found to fit the curves very closely as is shown in Fig. 6. From this it is evident that the increase in detonation due to carbon is proportional, not to the total carbon present, but to the greatest thick-

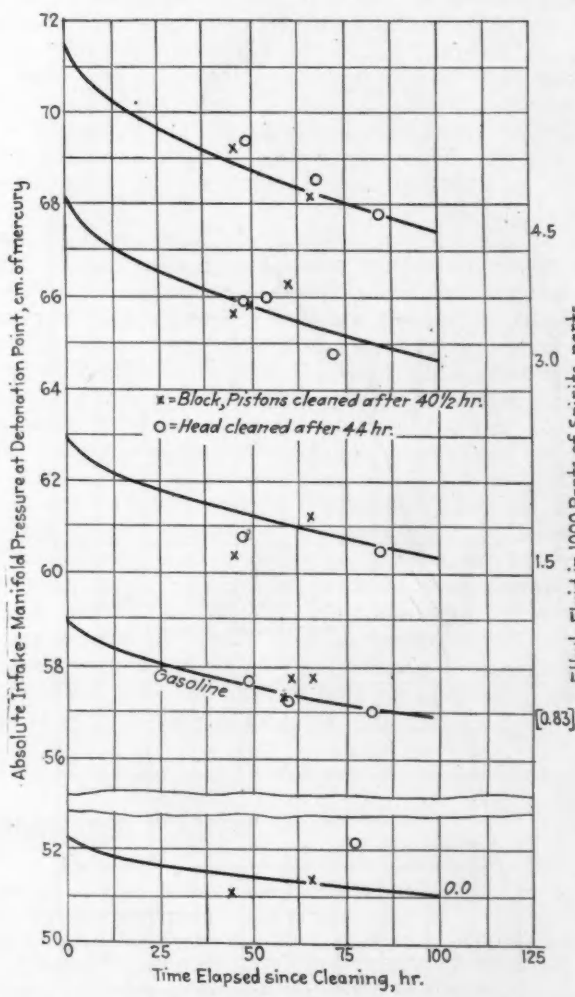


FIG. 6—EFFECT OF PARTIAL CARBONIZATION ON DETONATION

The Engine Was Carbonized for About 40 Hr. Then, Either the Cylinder-Head or the Remaining Parts of the Combustion-Chamber Were Scraped. Subsequent Calibrations Did Not Fit the Curves of Fig. 3, Where Detonation Is Related to the Weight of Deposit, But Fit the Curves of Fig. 1, Herein Transcribed. From This It Is Deduced That Detonation Is Proportional to the Greatest Thickness of Carbon Over Any Considerable Area

ness of carbon which covers an appreciable area of the combustion-chamber surface. The action of the carbon, both as a thermal insulator and as a black body absorbing radiant energy from the combustion and becoming highly heated thereby, tends to cause local overheating of the surrounding layers of gas. The data presented herein thus tend further support to the "local-overheating" theory of the origin of detonation.

Influence of "Carbon Remover" on Carbon Deposit

In reference to the influence of "carbon remover" on carbon deposit as regards both weight and detonation-increasing properties, paradoxically, the object of a carbon remover is not to remove carbon, but to prevent detonation. It is intended that this shall be accomplished by removing the carbon which induces detonation; however, if some compound were found which changed the deposit so that, although present in normal quantity, it no longer induced detonation, such a compound would be as good a "carbon remover" as one which actually kept the engine clean. It is known that some compounds have this property to a limited degree.

In general, carbon-deposition tests are therefore of no value per se, since the character of the deposit, as well as the weight, is a factor in the detonation-inducing tendency.

[5] M.S.A.E.—Chief car draftsman, Pierce-Arrow Motor Car Co., Buffalo.

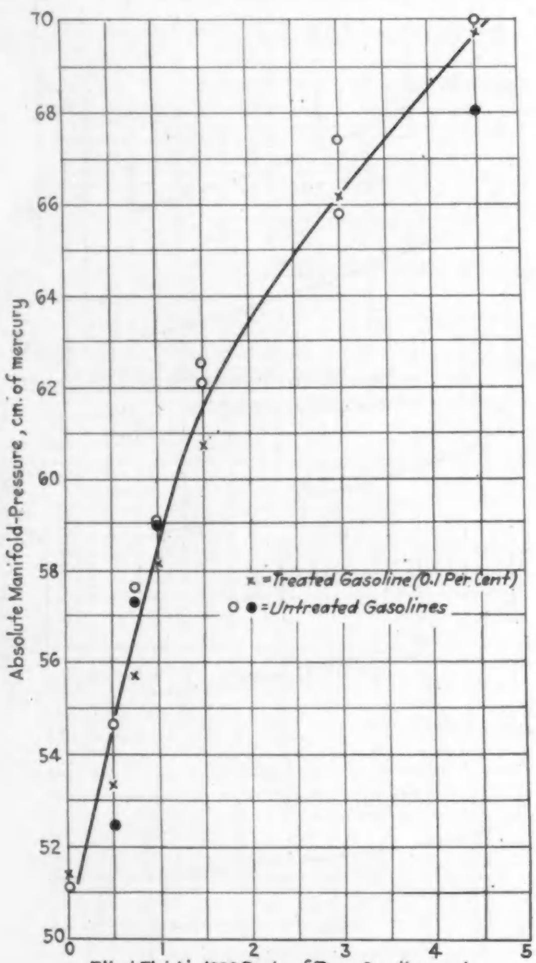


Fig. 7—Detonation Method of Testing Carbon Remover

Detonation Calibrations Made After 8 Hr. of Operation with Ordinary Fuel and With the Fuel Treated With 0.1 Per Cent of Popular Carbon Remover. This Method Eliminates Uncertainty as to the Character of Carbon Deposit, in Carbon-Remover Tests. Black Circles Represent Points Doubtful Because of Mechanical Mishaps

TABLE 1—ACTUAL WEIGHT OF CARBON DEPOSITS

Details	Untreated Gasoline,[4] Grams	Treated Gasoline, Grams
Deposit	8.72	9.37
Oil	0.86	1.27
Ash	0.71	0.73
Carbon	7.15	7.36

[4] Average of two runs.

A carbon remover should be tested, not on the basis of the comparative weight of the carbon deposit, but on the basis of the comparative detonation-inducing tendency of the deposit. With this in view, a test was made of a popular carbon remover, under the following conditions: The speed was 700 r.p.m. The intake-manifold absolute-pressure was 50 cm. (19.69 in.) of mercury. The temperature of the jacket water at the inlet was 100 deg. fahr. and that of the carbureter air was 200 deg. fahr. The oil was pale filtered, of 500-sec. viscosity at 100 deg. fahr. and kept at 130 deg. fahr. in the crankcase. The fuel was Texaco gasoline of 400 deg. fahr. end-point and the duration of the test was 8 hr.

Fresh oil was added every 15 min. to replenish the supply to the original level. The engine was equipped with a Stromberg carbureter using a No. 57 orifice, but having no needle-valve or idling-jet. At the end of the 8-hr. test-period, a calibration run was made on the series of standard fuels.

The calibrations for the two standard test-runs and the one test-run made with the specified quantity of carbon remover in the fuel, are plotted in Fig. 7. In the course of making one of these calibrations the spark-advance control slipped 4 deg.; therefore, black circles represent the points thus made doubtful.

Disregarding these doubtful points, it will be seen that the carbon deposition caused slightly more detonation when the carbon remover was used, than when untreated gasoline was used. The actual weights of the carbon deposits were as shown in Table 1. It will be seen that the two methods check fairly well in this case.

In evaluating such a test, it is suggested that the results of the detonation calibration be expressed as equivalent to the number of grams of carbon, which, formed under a set of standard conditions, would give a similar calibration. No simpler method of expressing a calibration based on a series of fuels has been deduced from the results so far obtained.

Conclusions Deduced from the Tests

From the test results given herein, the following deductions are indicated:

(1) In making detonation tests, carbon deposit should not be scraped frequently. The engine should operate as much as possible under constant conditions. If great dependence is to be placed on the results, tests should not be made immediately after scraping carbon

(2) Since the primary objection to carbon is its tendency to increase detonation, carbon-deposition tests should be superseded by detonation tests which will indicate the detonation-inducing tendency of the deposit

(3) The effect of engine carbon is to increase detonation in proportion to the greatest thickness of carbon existing over any considerable area

THE DISCUSSION

Chairman H. T. Youngren[5]:—Have you found a noticeable difference in various forms of combustion-cham-

ber which indicates that turbulence has a marked effect regarding the possibility of one type of head being able to have a greater carbon deposit than another without its effect being apparent through detonation?

NEIL MACCOULL:—We cannot answer those questions at present. In engines having various types of combustion-space, we know that there can be very high compression when no detonation occurs. I understand the question to be whether an accumulation of say 0.004 in. all over the heads will have the same tendency to increase detonation in all the heads, but I do not know the answer. During the work, when we first scraped the carbon from the cylinder-head and then from the piston-head, we found that apparently it is the thickness of the carbon on the piston-head rather than the quantity of carbon that causes the detrimental effect. For all types of head, any thickness of carbon probably will increase the tendency to detonate.

QUESTION:—What results have been obtained from the use of nitro-benzene?

MR. MACCOULL:—We know that nitro-benzene has a tendency to suppress detonation if added to a fuel, but a considerable quantity of it is required; in fact, the trouble seems to be that the ordinary quantity of nitro-benzene that is recommended for use is so small that we cannot determine, when using it, the effect it has in suppressing detonation. We know that a standard mixture of from 40 to 45 per cent of benzol has a great effect in suppressing detonation, but if 0.5 per cent of benzol is added we cannot tell the difference. The same is true of nitro-benzene. It must have some good effect, but the effect is so small that it cannot be measured when the proportion usually recommended is used.

A MEMBER:—It was recommended to me that I use 3 per cent by volume of aniline, with just enough benzol to dissolve the aniline. I have tried that on a 60-hp. engine without success. The compression-pressure is 63 lb. per sq. in.

CHAIRMAN YOUNGREN:—That is not considered very high compression at present. Compression-pressures average about 90 lb. per sq. in. at present in ordinary engines, and probably run up to 95 lb. per sq. in. in some commercial jobs.

MR. MACCOULL:—Aniline possibly is an alternative for "ethyl fluid," but it has a tendency to deteriorate. If about 5 per cent of aniline is used in a fuel, this will have the same detonation effect as say 40 per cent of benzol, which is very good, but we cannot use much more than 5 per cent of aniline without some additional solvent because it is not readily soluble in gasoline and it is expensive. When aniline is used, the quantity is so small that it does not interfere with the viscosity or with the heat value of the original fuel, as does the addition of benzol.

QUESTION:—What is the effect of turbulence?

MR. MACCOULL:—We believe that if every molecule of a gas mixture in a combustion-chamber were ignited by a spark, there would be no tendency for any particle to ignite by itself spontaneously, which apparently is the cause of detonation. In other words, we know from experience that the more spark-plugs there are in the cylinder, the less tendency there is toward detonation. The more the mixture is stirred up, the quicker will the flame from a spark-plug be spread among the molecules of the gas. Perhaps that is why turbulence decreases detonation.

ARTHUR NUTT[6]:—We place the spark-plugs exactly opposite in our engines. One spark-plug is fired considerably ahead of the other because we want the flames to meet in the center. We have an overhead-valve engine and the gas flows over the head, so we timed the exhaust spark 6 deg. ahead of the intake. I am led to believe that, in a four-valve engine having overhead valves, no such action, resulting from turbulence, exists and that the flow is all across the top of the head and not around it.

CHARACTERISTICS OF OILS

A MEMBER:—What has been done toward developing an aircraft-engine oil that will flow at a very low temperature and operate at a very high temperature?

MR. MACCOULL:—I cannot understand how an oil can be made that will not thin when heated. Oils are used only because they are viscous. Their viscosity changes with temperature. If the viscosity of any standard grade of oil is measured at various temperatures and the values are plotted in a special form of chart which we have developed, all the points will fall in a perfectly straight line. We have found no exception to this rule. So, for all practical purposes, if we know the viscosities of an oil at certain temperatures, say 100 and 210 deg. fahr., we can draw a straight line through the points and can determine without any laboratory work the viscosity of the oil at all temperatures. If this were done with four oils, such as our company's four grades of motor oil which are made from the same kind of crude oil, all four lines indicating viscosity are practically parallel. The characteristics of the crude oil from which the refined oil is made determine the slope of the line showing the viscosities of the refined oil. Generally, to maintain uniform viscosity during climatic changes, a Pennsylvania crude oil should be used as a base. But the trouble is that a paraffin-base oil invariably has some of its paraffin in the amorphous form, such as vaseline. The flow decreases with decrease in temperature until, finally, the oil will not flow. A paraffin-base oil ordinarily will congeal at 30 to 40 deg. fahr.

[6] M.S.A.E.—Chief engineer of the engine division, Curtiss Aeroplane & Motor Co., Inc., Buffalo.

WIDER ROADS FOR MORE CARS

IT is estimated that good roads now save the highway users $750,000,000 per year. Motorists pay the bulk of road-building expenses but probably profit the least by it. Land values have been enormously increased by highways, the benefits extending to farmers in remote sections. With the growth of our cities more and wider highways in their vicinity are a vital necessity, not only for passenger traffic but also to facilitate the transportation of food and supplies into the population centers.—American Research Foundation.

Technique of Sound Measurements

By FLOYD A. FIRESTONE[1] *Discussion of* DETROIT SECTION PAPER

ALL discussion of this paper at the October, 1926, meeting at the Detroit Section was extemporaneous. Each speaker received the edited transcript of his remarks for approval or correction before publication and the author was also afforded an opportunity to reply to any of the points raised in the discussion. For the convenience of those who desire to gather some knowledge of the subjects covered without referring to the complete text as originally printed in the November, 1926, issue of THE JOURNAL, *the abstract that appeared in that issue precedes the discussion.*

ABSTRACT

RESEARCH methods applied to the inspection of automotive parts for noise-producing causes are analyzed by the author, who notes the increasing tendency toward the use of sound-measuring instruments and discusses first the units of sound intensity and loudness. The dyne per square centimeter is a convenient size of unit for measuring the pressure amplitude of sound-waves, since 1 dyne per sq. cm. lies within the range of amplitudes at which the ear normally functions, being approximately that at one's ear when listening to conversation.

In calibrating at high frequencies, the thermophone is used. It consists of a small strip of thin platinum or gold a few centimeters long and about 1 cm. wide through which an alternating current of desired frequency is sent. The formula for the thermophone gives the "r. m. s.," or root mean square, pressure amplitude in dynes in terms of such easily measured quantities as the current through the strip, the resistance of the strip and some constants of the air.

Loudness as perceived by the ear is not a simple function of the intensity as measured by an instrument. Explanations of this fact are made and instruments for sound-intensity measurements are then described, the most successful methods involving the use of electrical apparatus. Analysis is made of the influence of the room in which the sound measurements are taken, as well as of frequency determination and filtering, the last being the exclusion from the measurements of sound that it is not desired to investigate. In conclusion, it is stated that although the paper emphasizes the difficulties of sound measurement, the difficulties actually exist and must be dealt with before progress can be made.

Main features of the discussion following the paper include questions and answers relating to whether different types of material affect the pitch of the noise produced; the result of sounding-box effect on transmission cases; and whether the frequency of noise or the intensity of noise is the more important.

THE DISCUSSION

K. L. HERRMANN[2]:—The information disclosed confirms very well some Studebaker experiments of about 5 years ago. A transmission that happened to have 16 teeth in a pinion was run at 1000 r.p.m. and produced the note middle C on the piano. Later, we found that corresponded to 256 oscillations per sec. and it showed a single fault in that particular gear. The second-speed gear produced another sound which, when compared with certain tones on the piano, also showed a single defect on the tooth. Going back down the scale we found the rattles in a single tooth on that pinion which caused the knock. If a tooth in the gear caused the note to jump an octave higher, immediately we looked for two defects in the gear. We were able to reduce this sound analysis to a decimal equivalent in the gear-tooth shape so that, finally, in a new machine which we had designed for cutting the gears, we obtained the required accuracy. We found that possibly 0.001-in. inaccuracy in a gear-tooth shape was enough to cause a bad noise.

QUESTION:—Do different types of material in gears affect the pitch of the noise produced, provided the gears are of the same size and shape?

PROF. FLOYD A. FIRESTONE:—We have made no experiments on any except steel gears, but my opinion is that the type of material would not affect the pitch, which is determined entirely by the number of teeth coming into contact. Since it is the number of teeth that mesh per second which determines the frequency with a steel gear, I would expect a fiber gear or one of any other material to produce the same pitch.

A MEMBER:—That is one of the peculiar things we seem to find difficulty with. As a representative of a metallurgical fraternity, that is one of the problems we frequently are asked to solve. Some members state that some gears treated in a cyanide bath have a higher pitch than those simply hardened in an electric furnace.

PROFESSOR FIRESTONE:—I can see a possibility of how that might come about. Those gears produce certain harmonic tones. They have a fundamental note and some harmonics. When we change the material, the relative importance of fundamental and harmonic notes may have changed so that the harmonic may have become loud enough to make some impression on the ears themselves, although it is actually a multiple of the pitch which we had before.

R. H. WEINERT[3]:—After the frequency in a note is determined, how do you find out where that particular noise comes from and how many different sources go to make up that one note?

PROFESSOR FIRESTONE:—If we determine the frequency of that note and it goes with the frequency at which a certain gear comes into mesh, then we say that this gear is probably responsible for that note. The exact place where that sound enters the body of a car

[1] Assistant professor, department of physics, University of Michigan, Ann Arbor, Mich.

[2] M.S.A.E.—Consulting engineer, Studebaker Corporation of America, South Bend, Ind.

[3] M.S.A.E.—Special engineer, Studebaker Corporation of America, Detroit.

we do not know, but we do know that the gear in question is responsible for the sound. It comes originally from the gear, although it is distributed around through the car.

MR. WEINERT:—I had reference primarily to valve mechanism and not to gears. In studying valve mechanism the noise comes from a number of places. We have other things to deal with in that case; namely, spring vibration, hammering of seats, slap of cam faces, movements of plungers, or various other objects, any one of which would affect the general noise.

PROFESSOR FIRESTONE:—The difficulty here is that there are a number of factors, all of which function at the same speed, so that one cannot separate them by this method of frequency analysis. I prefer to speak of gear noises because they are musical tones, but valve slaps do not go into my analyzer right. Of course, it is possible that a valve might slap fast enough so that it would give one's ear an impression of its being a definite pitch; if a number of valves slap at once, one might hear a musical tone from that. This method is not so useful when it comes to locating knocks in engines and valve slaps and the like.

QUESTION:—A suggestion was made several years ago by Prof. Earle Buckingham relative to pairs of gears in mesh. We always have two gears working at the same time. Now if we have a pitch ratio or frequency ratio of say 5 to 3, that has a definite musical harmony, a frequency of 5 to 7 might be less pleasing to the ear. What are the possibilities in the design of a transmission to maintain those pleasing harmonies and to avoid those combinations of two contact frequencies which would produce displeasing combinations?

PROFESSOR FIRESTONE:—That is a psychological question and is out of my field entirely. But if certain ratios of frequency are pleasing when we hear them from an orchestra, we expect them to be more pleasing when we hear them in a car. Of course, the trouble there is that the frequency is always changing as the speed of the car changes so that a certain chord does not impress one's ear so favorably when it is heard in a car.

QUESTION:—What is the result of the sounding-box effect on transmission cases? Has that been studied in relation to the sound that gears produce?

PROFESSOR FIRESTONE:—I have no experimental data to offer on that subject. The point always is, however, that no matter what kind of sounding-box effect one gets, the frequencies of the tones which come out will not be altered. The frequencies will be the same, but if any part of the transmission case should get into resonance with one of those frequencies, then the loudness due to that particular frequency would be very much increased. There is a great difference in the loudness of the sound created in the body, after the frequency changes. We always hear them say that gear noise comes in at 31 m.p.h. and disappears at 35 m.p.h. That seems to be something like a resonance effect.

QUESTION:—Which is of the more importance, the frequency of the noise or the intensity of the noise? Is it possible to construct an instrument which would tell us the intensity without going through all the various formulas of finding the frenquency? As I understand it, that is what determines whether a machine is noisy or quiet.

PROFESSOR FIRESTONE:—That word intensity is used rather differently. It is not very well defined ordinarily. Perhaps it is better to say loudness, because it is only the loudness that determines the final effect on the ear. We think that we can incorporate in our measuring apparatus, in the place of this analyzer which listens to one frequency only, a circuit that will weight the frequencies in the same way as the ear does so that the indication given on our dial is loudness instead of intensity.

INTERNATIONAL AUTOMOTIVE MARKETS

AUTOMOBILE manufacturing industries in Great Britain, France, Germany, and Italy are small but growing. Although the aggregate annual output in these countries is little more than 12 per cent of production in the United States, exports are approximately 40 per cent of the exports from the United States and constitute a measurable proportion of the automobiles entering international markets. Italy exports nearly three-fourths of its annual output, France over one-third and Great Britain from 10 to 15 per cent.

The relative percentage gain in registration of automobiles has lately been greater in other countries than in the United States. This situation is likely to become more pronounced in the future, depending on extent of industrial development and road construction on the more remote frontiers. In 1922 the cars and trucks in use in the United States were 84 per cent of the world total while by the close of 1925 this percentage had declined to 81. In Europe, on the other hand, registration increased from 8 per cent of the world total to 11 per cent in 1925. Similar percentage increases in relation to the total world registration were made in Australia, Asia and Africa.

British manufacturers are challenging the supremacy of the American automobile in colonial possessions and in South America. Nearly every British manufacturer has developed models with American features of design to meet colonial requirements in addition to the popular small models of low horsepower and low fuel-consumption produced for European markets where taxes and operating costs are high.

The achievements of the British automobile industry in production, although on a much smaller scale than in America, have nevertheless been striking. Production is nearly seven times the prewar output, and registrations have increased from 139,000 cars and commercial vehicles in 1913 to 960,000 in 1926, a gain of nearly 600 per cent.

In 1922 British manufacturers supplied only half of the cars operated in the British market; now three-fourths are manufactured at home. The imposition of import duties in 1925 established more securely the position of the British cars in the home market. Considering the sizes of the automobile manufacturing industries in Great Britain and in the United States, the former country now has relatively a much larger share of the Australian trade.

France next to Italy exports the highest proportion of its annual production. In 1925 exports amounted to 61,471 cars and trucks and in the first 10 months of 1926 exports amounted to 50,833 units. On the other hand, foreign manufacturers are experiencing difficulty in marketing cars in France, owing in part, no doubt, to unfavorable exchange rates for the French purchaser. From January to October, 1926, little more than 5000 cars and trucks of foreign manufacture were imported into France against 15,600 imported during the first 10 months of 1925. This situation exists despite the fact that representatives of 21 well-known American-made automobiles are located in France.

French manufacturers do not hesitate to adopt American engineering practices to reduce the cost of manufacture. Competition in both foreign and domestic markets has forced the adoption of methods and machines formerly considered

impracticable for use by European manufacturers. French engineers and purchasing commissions are sent to America to learn economies effected here and to purchase American machines regardless of unfavorable exchange rates. Toward the close of 1926 French production slumped sharply, partly because of seasonal causes but more largely because of fluctuation of the franc which resulted in a reduction of buying demand.

Italy exports a higher percentage of its production than any other country. Over 73 per cent of its output in 1925 was exported. From January to September, 1926, over 26,000 cars were exported, as compared with 22,000 in the first nine months of 1925 and 13,400 in the first three-quarters of 1924. The volume of exports has doubled within the last 3 years. The total value of the export trade in automobiles, not including parts and equipment, amounted to over 500,000,000 lire (approximately $20,000,000) in the first 9 months of 1926. Italian exports go largely to other European countries, but they have been making headway in the South American and other distant markets. The growth in registration of cars in Italy concurrently with the rapidly growing exports may be accounted for in a measure by increased imports.

One of the primary steps needed for the development of the domestic market in Italy is the upbuilding of a system of modern roads. Steps have been taken in this direction which, together with the industrial expansion that has taken place recently, may portend a larger domestic registration in the future. In Italy as in the United States, sales are stimulated by deferred payments. The geographical conformation of the country has hindered railroad development and in a measure has assisted the growth of public-carrier automobile lines. In 1924 these lines transported 30,000,000 passengers as compared with 100,000,000 conveyed by the state railroads.

The financial embarrassment of the Austrian industry is forcing it to change from a manufacturing to an assembling industry. A step in this direction has already been taken by one of the companies in starting the assembly of motor trucks from American-made parts.

The German automobile industry has made rapid progress in the last 2 years. In 1911 the output was 16,939 units. By 1922 production had recovered somewhat from wartime disorganization and amounted to about 46,000 units. In 1925 output increased to 70,000 units, which constituted probably a new high record. Efforts are being made toward standardization and "rationalization"; that is, the writing-down of unprofitable capital investment and elimination of uneconomic equipment. One of the chief drawbacks to the possibility of increasing export sales was the high-production-cost, which was kept high in part by the great number of models manufactured. Much has been accomplished in this direction. In 1923, 77 manufacturers exhibited 118 models. By the middle of 1926 the number of plants was reported to be about 30, with only 43 various types of automobile on exhibition. Even with that great reduction, the number of models is still large for economical production.

Although the registration per capita of automobiles in Germany is lower than in other important European countries except Italy, and in relation to economic wealth is lower than in almost any other country of the world, a marked increase in automobiles has occurred in the last 4 years. Passenger-car registration has increased from 100,000 in 1923 to over 200,000 in 1926. Trucks in use advanced from about 52,000 in 1922 to 90,000 in 1926. High operating-cost no doubt restrains more rapid growth in registration. Total maintenance-cost for a low-priced American car including the annual taxes is estimated at 2500 to 3000 marks (approximately $600 to $720) annually. The protection afforded by the tariff has secured for the German producers a fairly strong hold on the domestic market. It has been estimated that approximately 70 per cent of the cars in Germany are of domestic origin. For the last 2 or 3 years imports have greatly exceeded exports with the exception of a period in which a temporary embargo was placed on importations of foreign cars. In recent years exports of passenger automobiles from Great Britain to Germany have been increasing. Uneconomic producers are being rapidly eliminated, consolidation and coordination of forces have reduced costs, modern equipment has been installed and mass-production methods have been adopted in several plants. and financial rehabilitation has reached the stage where the industry has attracted the attention of American as well as European investors.

The competitive power of European producers in the international market is clear in the case of such products as iron and steel, textiles, glass, cement, and the like, where the manufacturer has been able to combine the economies of low labor-cost and large-scale output. These commodities are sold in the important markets of the world in competition with the American products, and on occasions even flow over tariff barriers into our own domestic markets. With due recognition of the dominant position of the American industry in the export field, the outlook is for greater competition in international automotive markets.—*Commerce Monthly*.

PROGRESS OF CIVIL AVIATION IN BRITAIN

EACH year sees a steady increase in the volume of traffic passing by air, and the annual report on the progress of civil aviation during 1926 confirms the impression that the strides made in this country during the period under review have been fairly rapid. Thus, during 1926 Imperial Airways, Ltd., carried no fewer than 16,775 passengers as compared with 11,193 in the previous year, an increase which amounts to approximately 50 per cent, while the tonnage of goods handled, which in 1925 was 550, reached 679 tons during the succeeding 12 months. That there is also a growing feeling of confidence in the safety of civil aviation is proved by the fact that so-called "joy-riders" have increased enormously, 215,000 miles being flown and 81,909 passengers having been carried during the year, both of which figures dwarf any that have previously been recorded, while a further gratifying fact is that the British share of the cross-Channel traffic, which had declined to 51 per cent in 1925 when the British fleet was inadequate, has now risen to its former level and stands at 61 per cent. So far as the value of the goods carried is concerned, while imports dropped in value from £1,183,175 (approximately $5,679,240) in 1925 to £958,237 (approximately $4,599,538) in 1926, the value of the exports has been more than doubled during the same period, the actual figures being £403,761 and £966,003 respectively (approximately $1,938,053 and $4,636,814). The carriage of bullion and gold and silver coin, which traffic has from the first been recognized as peculiarly suitable for transport by air, seems to be well established, the value handled in 1925 being £10,040,399 (approximately $48,193,915) and during last year £8,283,498 (approximately $39,761,190). Finally, it is encouraging to find that for the second consecutive year British air transport has the proud record of having suffered no accidents resulting in death or injury, although 1926 witnessed one fatal accident in "joy-ride" flying, where a passenger was killed by falling out of the airplane. When it is remembered that 1926 was also noteworthy for the achievement of a number of epoch-making flights—such, for instance, as Sir Alan Cobham's and the inauguration of the Egypt to India route—it must certainly be recognized that British civil aviation is at the present time making a really strong bid for popularity and success.—*Modern Transport*.

Vol. XXI July, 1927 No. 1

Operation and Maintenance

By J. F. WINCHESTER[1]

TRANSPORTATION AND SERVICE MEETING PAPER *Illustrated with* PHOTOGRAPHS AND CHARTS

ABSTRACT

SINCE advances in design of automotive vehicles and service equipment have been rapid they should be considered when using past costs as data from which to figure costs with new equipment. The effect of improvements should also be considered in the selection of new equipment and in deciding when to make replacements.

Prejudice based on performance of war-time vehicles should give way to the latest information. Four-wheel drives, track layers and six-wheel vehicles have their uses. Specifications must fit the vehicle to present and prospective jobs. Great discrepancy is noted in weights of different trucks of the same rated capacity, only partly accounted for by different types of tire. Changes in recommended inflation-pressures of pneumatic tires have caused confusion among service men of a sort that interferes with a reduction of costs and thus hinders the extension of automotive transportation. Training of transportation and service executives is of the utmost importance. Examples of good training schools are cited.

Poor service stations have hindered the progress of many manufacturers and have caused many owners of small fleets to make their own repairs. Service cannot be given economically without the advantages of good equipment and experience. There are many engineering problems connected with the service stations. Each accounting system must fit into the general accounting system of the fleet owner. It is important to record costs of individual units in order to find where costs are high and to check up on the advantages of new models. Careful advance estimates of overhauling and repairs guide in deciding what work to do and when to retire the vehicle. Sample forms are shown.

THE automobile industry is hardly more than 25 years old if we consider it from a viewpoint of mass production, operation or maintenance. The strides that have been made in every line of engineering are phenomenal. The lessons learned from operation and maintenance have been applied to designing with marvelous results toward simplicity. Associated engineering and other lines have gone into many of the problems affecting operation and have advanced many ideas of great value, while production and service specialists have made studies that have resulted in a marked effect upon initial and repair costs.

My object in referring to these results is to lay the foundation for some of the ideas contained in this paper to the effect that past cost figures for automotive transportation should not be accepted as a strict criterion when future transportation problems are considered; because the rapid changes along various lines have resulted in a considerable improvement in operating costs during the last 10 years and should continue to produce better results provided business is properly conducted.

A motor-vehicle can be used as a medium of economical operation only by making the proper selection for a given line of work. Both the job at hand and the future work of the vehicle must be carefully considered, as well as the general road and the climatic and load conditions under which it will operate. Such considerations indicate the specifications, which must vary in a given make of vehicle for various lines of work and different localities. These specifications will indicate whether it shall be a rear-wheel or four-wheel drive, a tractor or caterpillar type, also the sizes of engine and tires, the gear-ratio, wheelbase, body design, and accessories.

A detailed study of the mechanical design is important, particularly with the thought that recent designs may make possible a reduction of operating and repair bills. This naturally leads to a question of replacing the older vehicles in a given fleet with some of later design.

I have seen mistakes in the original specifications or selection of vehicles charged up to maintenance or repairs when they should have been recognized as due to wrong selection or specifications of the original vehicle, to manufacturer's poor service organization or to high-pressure salesmanship. These mistakes have occurred principally because the firm making the installation had neglected to call in competent, disinterested engineers to analyze their problem.

DEFINITE MECHANICAL IMPROVEMENTS

Advances in mechanical design during the last few years have been of such an outstanding character that it might be well to point out some of them. The following have an important bearing on maintenance costs: air-filters, oil-filters, oil-rectifiers, Ricardo heads, large water-pumps, changed radiator design, changed cab design, changed spring design, better transmission ratios and more general adoption of four-speed transmissions, auxiliary shock-absorbing devices of various types applied to the springs, refinements in oiling systems, crankcase ventilation, lighter chassis, and, most important of all, improved materials in vital parts.

Now let us consider chassis weights. There is no established standard of weight for carrying a given load. There is a wide variation between various makes of chassis, as illustrated by the following sample weights of chassis with open cab:

Rated Size of Vehicle, Tons	Weight of Chassis, Lb.
1	1,500
¾-1¼	2,980
1½	5,750
2	4,025
2½	4,615
2½	5,850
2½	5,900

Judging from past experience we might say that many chassis are too light and not substantial enough, but we must take into consideration that weight and tire equipment have an important relation to one another. We cannot economically use solid tires on many of the lighter vehicles because vibration will quickly send them to the

[1] M.S.A.E.—Superintendent of motor equipment, Standard Oil Co. of New Jersey, Baltimore.

shop. We can use pneumatics upon a chassis designed for solid tires, but the tire expense will be found to be higher than is necessary because of the excessive chassis-weight.

From the list shown and from my observations I am personally certain that there is a distinct opportunity for engineers to improve the ratio of weight to load in some cases. It seems ridiculous to designate as a 1-ton job a vehicle weighing 1500 lb. when the nearest approach to this is a vehicle designated as $\frac{3}{4}$ to $1\frac{1}{4}$-ton capacity with a chassis weight of approximately 2980 lb. Other similar discrepancies can be found in the list. These chassis weights all represent standard jobs upon the market today and the figures quoted are correct, considered with a cab as part of the chassis. It is difficult to reconcile such differences in weights for different capacities, but if one has access to cost records it is usually easy to determine which type of vehicle is best suited for performing a given job.

What Type of Tires?

This naturally leads into a question of the type of tire to employ for a given vehicle and has a material bearing upon the probable mechanical upkeep and tire cost. A state of transition exists, making this a subject worthy of very careful consideration by all concerned.

The tire industry has certainly placed the operator in a very difficult position. I remember distinctly that, 12 or 14 years ago, dual pneumatic tires were the recommended tire equipment for the rear for light trucks. Fault was found with these in operation and single tires were recommended. We now find the tire companies again recommending dual in preference to single equipment. In the past our problem has been to keep tires up to pressure, and high pressures only were recommended. Today we are faced with a change of front and instead of high pressure it is now recommended that low pressure be used.

During such changes it is only natural for the advertising departments to jockey for the best position for their own product, with the natural result that there springs up a great deal of misleading information.

Such points must be definitely settled if we are to continue by means of reduced costs to extend motor transportation into fields wherein it has been deemed inadvisable up to the present time to employ this type of transportation.

Let Facts Dispel Prejudice

Considering the type of vehicle as a whole, prejudices often spring up that should not be retained after designs have been improved. An example of this is the four-wheel drive. There is a definite field for this type of vehicle. We are inclined to judge the type from experience with war-time designs and products, made under the stress of conditions that resulted in vehicles being turned out that were not altogether satisfactory in various ways. Many of our boys encountered them in France and we still come into contact with them in State highway work, with the result that their reputation is not of the best. The same is true of the caterpillar-drive type. However, an investigation of this subject will show that distinct improvements have been made, and application of such vehicles of improved design might result in reduced maintenance in a given field. Figs. 1 and 2 show a four-wheel-drive truck, both without load and loaded, operating under severe conditions.

In truck and motorcoach design we see a tendency to experiment with six-wheel vehicles. This seems a logical way to reduce road shock and permit carrying a larger pay-load, as it distributes the load over a larger area of road and reduces road shock.

Tests[2] conducted by the Bureau of Public Roads, some of them in conjunction with this Society and the Rubber Association of America, show that stresses on the road from a six-wheel truck are approximately half those caused by a four-wheel truck carrying the same load. These are favorable factors for carrying heavier loads without serious damage to the highways.

With improvements in highways, terminal facilities, vehicles, and general operating conditions, together with the recognition that automotive transportation is an economic necessity, there is a decided tendency toward closer engineering study of the many points involved. Formerly many executives have merely glanced over and disregarded engineering advice, but it appears to me that there is a decided tendency for large companies to pay more attention to the engineering phase of their business, and this is resulting in attractive employment opportunities for men with training in engineering fundamentals that fits them to coordinate and solve the problems that arise.

We Must Train Men

The education of personnel is important. It has been neglected in the operation and maintenance end of the industry. There has been a tendency for executives and engineers in high positions to scoff at the lack of fundamental training of the men with whom they come in contact, when the fault could be traced, in many instances, to their own short-sightedness. Of all the factories I have visited, the outstanding one in the industry for educating future service men and mechanics in general transportation is the Ford Company. Henry Ford is a man who is not scoffing at the men who handle service in his branches; he is backing his practical ideas with his pocket-book, and making better all-round men. Anyone present who has in mind trying to adopt some educational methods for future service men should visit the United Shoe Machinery Co., at Beverly, Mass., or the General Electric Co., at Lynn, Mass., and study the vocational training courses of these organizations. Also you should influence our own Society to do its part.

The possibility that transportation and service costs will be more satisfactory in future than in the past depends largely on better trained personnel and a greater number of modern service-stations.

One illustration of the consideration that these problems are receiving at the present time by communities as well as individuals is that in the revised charter of the City of Baltimore the transportation problem is recognized by the establishment of a Bureau of Transportation, organized with the object of saving approximately $50,000 per year in a group of about 400 to 500 vehicles. Another is found in Norfolk, Va., where the City Manager made a careful study of the entire subject and effected great economies, together with an improvement of service.

In New York City it was reported to the President of the Board of Aldermen on May 15, 1926, that 1129 passenger-vehicles of various makes and styles, valued at $1,175,161, were owned by the City; and that appropriations for the purchase, operation and maintenance of motor equipment of all types, excluding that of the Police, Fire and Street-Cleaning Departments, have increased from $570,175 in 1917 to $3,011,222 in 1926. This report states the increase in reality to be much greater, as the

[2] See *Public Roads*, October, 1925, p. 165; and June, 1926, p. 79.

Fig. 1—Four-Wheel Drive in Hard Going
Truck Will Operate in Sand or Gravel Where Two Drive-Wheels Will Dig In

above figures do not include allowances for automobile expenses and other items, amounting to a considerable sum, paid from various budgets. It is pointed out that this rapidly growing expense has become a considerable factor in a city's large expenditure, and that only a few of the great departments of the city require more money than is spent annually to maintain its passenger-cars. Only by the careful supervision of a competent engineer can economical results be obtained.

Servicing of Vehicles

We can all picture the village smithy of Longfellow's poem and the conditions under which he worked, and we know how ineffectual has been the attempt to continue the same type of shop for the repair of automobiles. This attempt brought disrepute upon the automotive industry. The policy of conducting service stations or smaller repair-shops along blacksmith-shop lines is passing into oblivion. It will surely lead organizations that attempt to follow such a policy into high costs, with resulting curtailment of dividends and ultimate bankruptcy. Proper working conditions, such as well-lighted, well-ventilated, sanitary shops, place the service end of the business on a higher plane.

Care and up-keep of most automotive equipment that is operated in fleets of four or more is handled by the owners in their own shops. This condition is possibly the result of neglect on the part of the manufacturer or his agent who failed to see the opportunity for profitable service to his customers. Or the condition may be due to competition in the industry through the slogan, "Free Service," that was formerly so glibly offered by the salesman who, in the majority of cases, had no real interest at stake except the original commission. Many of you are familiar with exorbitant service charges that have been rendered to customers requiring repair work, and others know the satisfaction of doing their own work, instead of having it done by outside organizations whose high charges have forced the user into the repair business. But we must all realize that it is not profitable for the small operator to maintain his own force if the agent of the manufacturer conducts his service business upon modern business-lines. No operator of a small group of vehicles can afford to install the tools necessary for proper maintenance and he should not be obliged to divert his efforts from his real business to study these details of economical transportation.

Many service organizations still have a long way to go before they will attract to them the business that should legitimately be theirs, but I am inclined to believe this situation shows improvement. The operator of the service station who visualizes his opportunity and picks and trains his personnel properly should be in a position to service properly a large clientele among those who have previously been driven to the establishment of their own repair-shops.

OVERHAUL JOB INFORMATION **REPAIR GARAGE AT**..................

EQUIPMENT NUMBER	SIZE AND MAKE	CHASSIS		ENGINE		BODY		TRANSMISSION		FRONT AXLE		REAR AXLE		STEERING COLUMN		ELECTRICAL WORK		BLACKSMITH		CARPENTER		TINSMITH		PAINTING		INSPECTION										TOTAL	
		HR.	I.C.	HR.	I.C.	HR.	I.C.	HR.	I.C.	HR.	I.C.	HR.	I.C.	HR.	I.C.	HR.	I.C.	HR.	I.C.	HR.	I.C.	HR.	I.C.	HR.	I.C.	HR.	I.C.	HR.	I.C.	HR.	I.C.	HR.	I.C.	HR.	I.C.	HR.	I.C.

Fig. 3—Tabulated Summary for Foreman
Total Time Charged on Each Job to Date Is Reported to Foreman Every Day. When Completed the Figures Are Shown on This Summary

The manufacturer should realize that he has a service problem and should supply his service stations with a line of tools to perform economically the work that will come in. He has the benefit of engineering skill, experimental work, together with the experience acquired by the design of production tools; but unfortunately the majority up to this time have neglected to see that keeping the product in reasonably good condition is their direct responsibility.

Fig. 2—Loaded Four-Wheel-Drive Truck
Loads Can be Carried over Rough Ground Even with Poor Footing

Modern Shop-Equipment Needed

Material strides have been made in the design of equipment to make proper and long-lived repairs. We have found that some tools have become obsolete, since later tools save time enough to make it profitable to replace the old. I will mention two such examples. We have found that the use of line reamers instead of single-point boring-tools for connecting-rod and main bearings results in a more-accurate job, both as to alignment and completeness of bearing-surface, and requires much less hand work. Also we have found that the steel metal-cutting type of valve-reseating tool is outofdate, because of the large amount of material such a tool removes as compared with the special seating-tool of a carborundum composition now on the market, resulting in shorter life

of the cylinder-block. In addition to this saving in cylinder life we obtain, by grinding, a valve and valve seat seated accurately enough to permit the practical elimination of hand valve-grinding.

The story of a visit to one of our shops illustrates the lax conditions that exist in some service stations in regard to tools. I noticed a strange, special tool and inquired about its use and where it came from. Upon being told, I asked: "How do you happen to have it here"? The answer was: "The service station sent it over to us to find out what it was for and how to use it." This was a case of a tool designed for a special purpose but not properly followed up by information from the factory.

Special tools of various characters are a necessity for time saving. Without them old-time hand-methods must be used, but in no case is it wise to select tools without a careful study of their merits. In many cases money is wasted on tools and equipment unsuited for the purpose, acquired simply on the basis of sales talk, because the organization has no one capable of making such a study. Electric or pneumatic drills, special machine-tools, washing-machines, and air-compressors illustrate this point. The last is a good example because it is usually subjected to considerable abuse and needs to have foolproof mechanism that will function properly at the minimum cost for current. A proper study of the various compressors on the market would involve consideration of approximately 36 various factors, evaluating them on a fair basis so that the actual worth could be fixed and compared to the sales price. Any shop or service station of any magnitude must be organized upon industrial engineering lines if it is to be operated properly.

Accounting Systems

Most operators employ systems of accounting adapted to their own individual accounting methods that were established long before motor-vehicle transportation came into general use. The important thing to be accomplished by any transportation accounting system is to furnish promptly a record of the transactions that have taken place.

Most accounting systems that I have seen have given no consideration to the detailed operation-cost of the individual units constituting the vehicle. To be certain that overhaul costs are reasonable it is necessary that each unit be repaired and accounted for on an individual basis. To keep before us continually the progress of the work through the shop, we employ a system with this feature that gives to the foreman each day a report of the time charged to a given job up to the current day. At the end of the work this is summarized and we then have a detailed account of the cost charged against each unit. This gives us a basis for direct comparison and enables us to put our work through the shops practically on a flat-rate basis. In the course of time we accumulate an amount of definite data that gives us a clear idea of the comparative performance of earlier and later models of a given make, or of different makes. Fig. 3 shows the summary that is made up for each unit or complete vehicle that passes through our repair-shop.

To determine whether it will be more economical to overhaul or to repair a vehicle, we make an estimate on the work before it passes through the shop. This estimate is made on standardized forms with the common repair-operations listed and with blank spaces for other operations that may be needed. Four of these estimate sheets, each $8\frac{1}{2} \times 13\frac{1}{2}$ in., are required for a complete truck. The first and last of these are reproduced as Figs. 4 and 5. The second sheet lists operations on the cab, dash and windshield; the front axle; and the propeller-shaft and rear axle. On the third sheet are radiator, springs, frame, shields, fuel tanks, and load tanks.

Usefulness of Forms

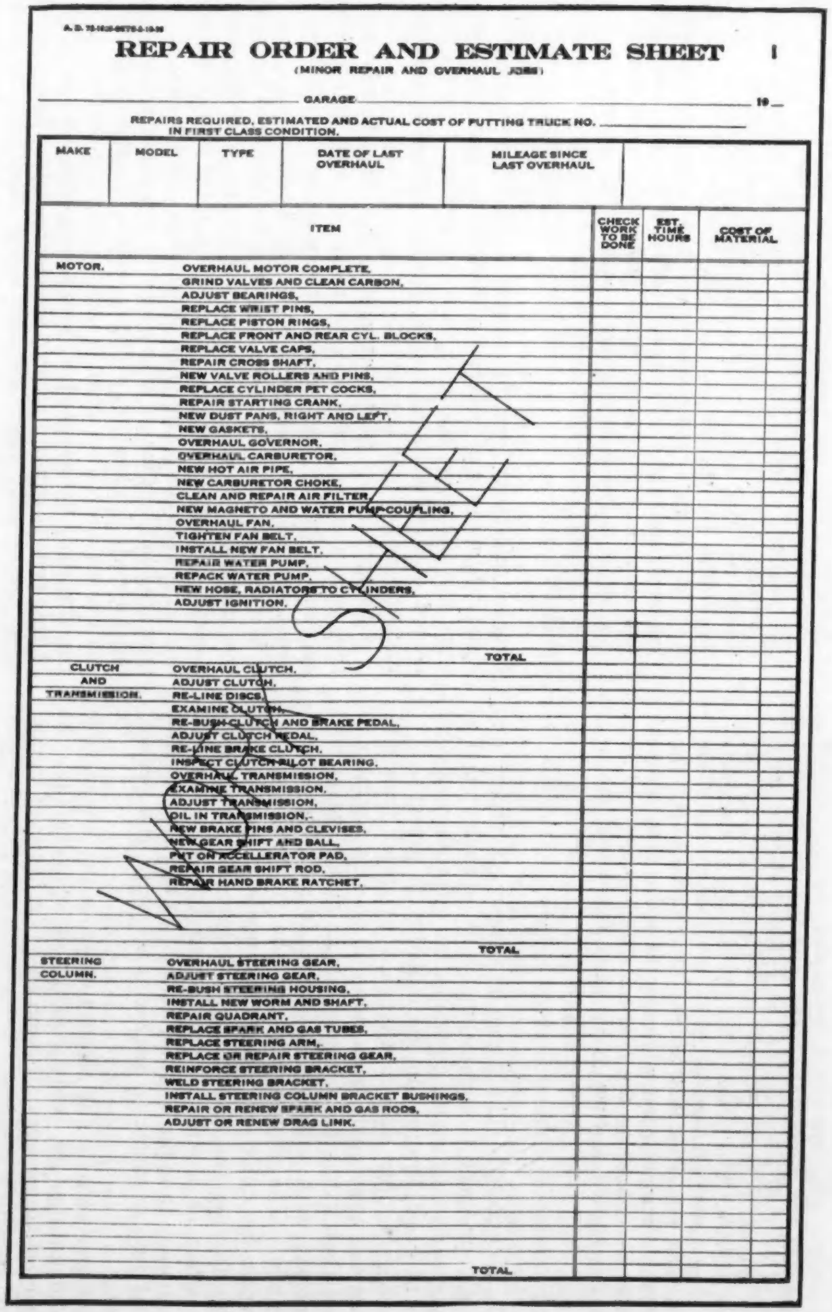
From the estimate, together with our general experience and past records, we are able to determine accurately whether a vehicle should be overhauled, salvaged or traded in. As these estimate sheets are used in the various shops we can judge their relative efficiency, and after a job is completed we have a very complete record of the cost to compare with the estimate.

Check figures of this kind are the most important records that we can maintain. They place clearly before us a complete picture of each job that comes into the shop. If any standardized system of accounting should be considered by the Society, it seems to me that something along these lines should be considered, for through the establishment of a simple outline of this character we would be able to encourage small operators to study their detailed costs. Vehicles should be judged by a comparison of actual mechanical performance. They cannot be correctly judged unless some system such as this enables you to place your finger on the factors that affect the operation favorably or otherwise.

One of our foremen has suggested and developed a blank that is of considerable help in writing requisitions. This blank lists the correct names and part-numbers of the various parts in a unit of some particular make and model of vehicle, with blank spaces opposite each item in columns headed: Location, Quantity, Price, and Amount. There are blank spaces provided at the top of the form for date and serial numbers and at the bottom for signatures. This blank saves the time the mechanic would spend searching through the parts books, prevents making out unsatisfactory requisitions and reduces the number of requisitions required for each job. This is a type of form that could be used with great success by many manufacturers and operators of large service shops where repairs are conducted upon a unit basis. The idea of keeping costs on a unit basis could be carried a step further by billing the owner on the unit basis. Properly coordinated with engineering, service and sales, such information would be of great value to the manufacturer and would eliminate a great deal of guessing as to the service costs of units.

Automotive transportation of materials is in its infancy. Do not "cramp" the business by living in the past. We are living in a scientific age in which the approved method is to test theories by honest study of facts. If dogma and facts differ, dogma loses. Willingness to yield preconceived opinion when annulled by new knowledge is one of the signs of intelligence.

Visualize the results that can be obtained from vehicles that are capable of covering twice as many miles as those of 5 or 6 years ago before they need complete overhauling. Lift the hood of your business, cast aside preconceived ideas, standardize on efficient, uptodate models instead of on names, and you will have gone a long way toward solving the problem of excessive maintenance and overhaul costs.



REPAIR ORDER AND ESTIMATE SHEET 1
(MINOR REPAIR AND OVERHAUL JOBS)

GARAGE ______ 19__

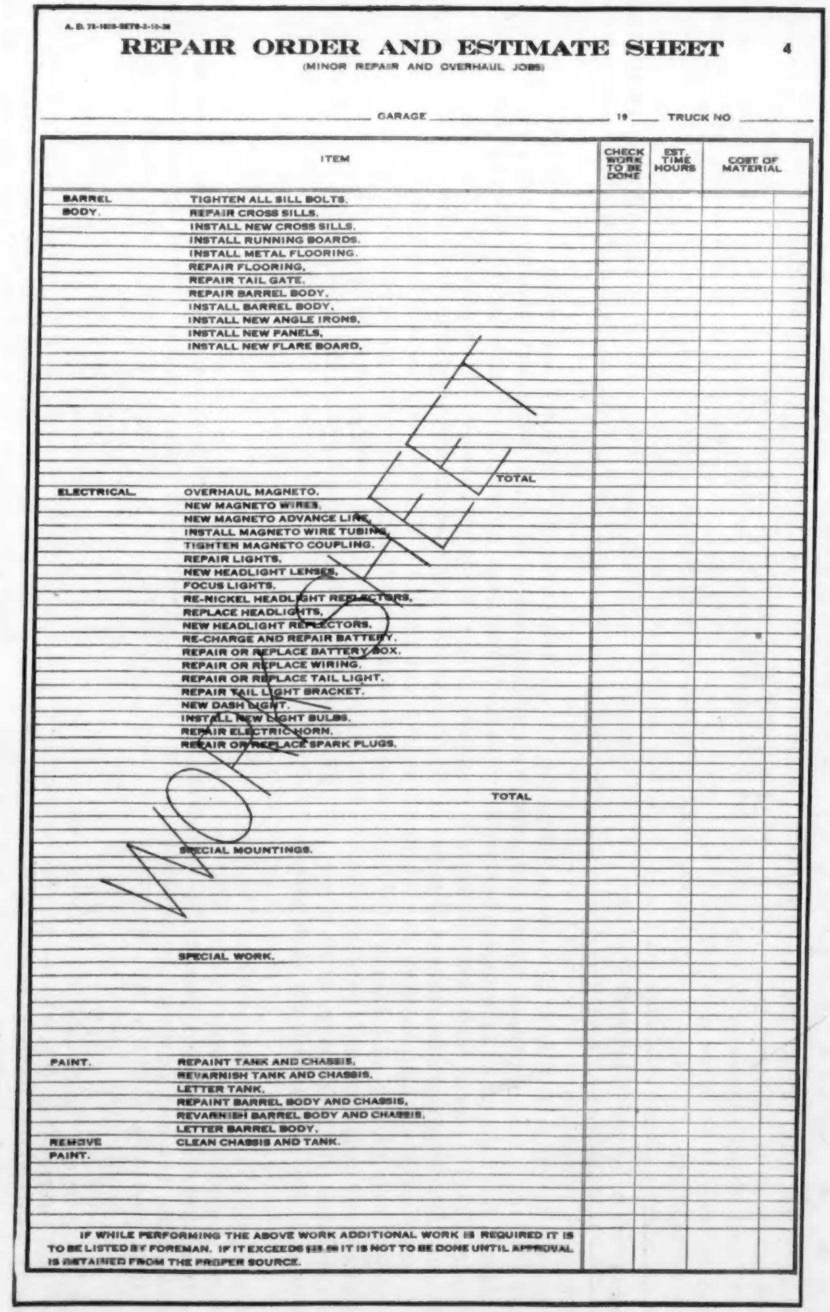
REPAIRS REQUIRED, ESTIMATED AND ACTUAL COST OF PUTTING TRUCK NO. ______ IN FIRST CLASS CONDITION.

MAKE	MODEL	TYPE	DATE OF LAST OVERHAUL	MILEAGE SINCE LAST OVERHAUL	

	ITEM	CHECK WORK TO BE DONE	EST. TIME HOURS	COST OF MATERIAL
MOTOR.	OVERHAUL MOTOR COMPLETE.			
	GRIND VALVES AND CLEAN CARBON.			
	ADJUST BEARINGS.			
	REPLACE WRIST PINS.			
	REPLACE PISTON RINGS.			
	REPLACE FRONT AND REAR CYL. BLOCKS.			
	REPLACE VALVE CAPS.			
	REPAIR CROSS SHAFT.			
	NEW VALVE ROLLERS AND PINS.			
	REPLACE CYLINDER PET COCKS.			
	REPAIR STARTING CRANK.			
	NEW DUST PANS, RIGHT AND LEFT.			
	NEW GASKETS.			
	OVERHAUL GOVERNOR.			
	OVERHAUL CARBURETOR.			
	NEW HOT AIR PIPE.			
	NEW CARBURETOR CHOKE.			
	CLEAN AND REPAIR AIR FILTER.			
	NEW MAGNETO AND WATER PUMP COUPLING.			
	OVERHAUL FAN.			
	TIGHTEN FAN BELT.			
	INSTALL NEW FAN BELT.			
	REPAIR WATER PUMP.			
	REPACK WATER PUMP.			
	NEW HOSE, RADIATORS TO CYLINDERS.			
	ADJUST IGNITION.			
	TOTAL			
CLUTCH AND TRANSMISSION.	OVERHAUL CLUTCH.			
	ADJUST CLUTCH.			
	RE-LINE DISCS.			
	EXAMINE CLUTCH.			
	RE-BUSH CLUTCH AND BRAKE PEDAL.			
	ADJUST CLUTCH PEDAL.			
	RE-LINE BRAKE CLUTCH.			
	INSPECT CLUTCH PILOT BEARING.			
	OVERHAUL TRANSMISSION.			
	EXAMINE TRANSMISSION.			
	ADJUST TRANSMISSION.			
	OIL IN TRANSMISSION.			
	NEW BRAKE PINS AND CLEVISES.			
	NEW GEAR SHIFT AND BALL.			
	PUT ON ACCELLERATOR PAD.			
	REPAIR GEAR SHIFT ROD.			
	REPAIR HAND BRAKE RATCHET.			
	TOTAL			
STEERING COLUMN.	OVERHAUL STEERING GEAR.			
	ADJUST STEERING GEAR.			
	RE-BUSH STEERING HOUSING.			
	INSTALL NEW WORM AND SHAFT.			
	REPAIR QUADRANT.			
	REPLACE SPARK AND GAS TUBES.			
	REPLACE STEERING ARM.			
	REPLACE OR REPAIR STEERING GEAR.			
	REINFORCE STEERING BRACKET.			
	WELD STEERING BRACKET.			
	INSTALL STEERING COLUMN BRACKET BUSHINGS.			
	REPAIR OR RENEW SPARK AND GAS RODS.			
	ADJUST OR RENEW DRAG LINK.			
	TOTAL			

WORK SHEET

FIG. 4—FIRST SHEET OF REPAIR ESTIMATE BLANK
The More Frequent Major Repair Operations Are Listed, with Blank Spaces for Additional Operations



REPAIR ORDER AND ESTIMATE SHEET 4
(MINOR REPAIR AND OVERHAUL JOBS)

______ GARAGE ______ 19__ TRUCK NO ______

	ITEM	CHECK WORK TO BE DONE	EST. TIME HOURS	COST OF MATERIAL
BARREL	TIGHTEN ALL SILL BOLTS.			
BODY.	REPAIR CROSS SILLS.			
	INSTALL NEW CROSS SILLS.			
	INSTALL RUNNING BOARDS.			
	INSTALL METAL FLOORING.			
	REPAIR FLOORING.			
	REPAIR TAIL GATE.			
	REPAIR BARREL BODY.			
	INSTALL BARREL BODY.			
	INSTALL NEW ANGLE IRONS.			
	INSTALL NEW PANELS.			
	INSTALL NEW FLARE BOARD.			
	TOTAL			
ELECTRICAL.	OVERHAUL MAGNETO.			
	NEW MAGNETO WIRES.			
	NEW MAGNETO ADVANCE LINK.			
	INSTALL MAGNETO WIRE TUBING.			
	TIGHTEN MAGNETO COUPLING.			
	REPAIR LIGHTS.			
	NEW HEADLIGHT LENSES.			
	FOCUS LIGHTS.			
	RE-NICKEL HEADLIGHT REFLECTORS.			
	REPLACE HEADLIGHTS.			
	NEW HEADLIGHT REFLECTORS.			
	RE-CHARGE AND REPAIR BATTERY.			
	REPAIR OR REPLACE BATTERY BOX.			
	REPAIR OR REPLACE WIRING.			
	REPAIR OR REPLACE TAIL LIGHT.			
	REPAIR TAIL LIGHT BRACKET.			
	NEW DASH LIGHT.			
	INSTALL NEW LIGHT BULBS.			
	REPAIR ELECTRIC HORN.			
	REPAIR OR REPLACE SPARK PLUGS.			
	TOTAL			
	SPECIAL MOUNTINGS.			
	SPECIAL WORK.			
PAINT.	REPAINT TANK AND CHASSIS.			
	REVARNISH TANK AND CHASSIS.			
	LETTER TANK.			
	REPAINT BARREL BODY AND CHASSIS.			
	REVARNISH BARREL BODY AND CHASSIS.			
	LETTER BARREL BODY.			
REMOVE PAINT.	CLEAN CHASSIS AND TANK.			

IF WHILE PERFORMING THE ABOVE WORK ADDITIONAL WORK IS REQUIRED IT IS TO BE LISTED BY FOREMAN. IF IT EXCEEDS $25.00 IT IS NOT TO BE DONE UNTIL APPROVAL IS OBTAINED FROM THE PROPER SOURCE.

WORK SHEET

FIG. 5—LAST SHEET OF REPAIR ESTIMATE BLANK
Sheets 2 and 3 List Operations on Other Units. Cost Estimates Help in Deciding How To Handle Work

A Four-Speed Internal-Underdrive Transmission

By C. A. NERACHER[1] AND HAROLD NUTT[2]

Discussion of ANNUAL MEETING PAPER *Illustrated with* DIAGRAMS

THE discussion following the presentation of this paper at the Annual Meeting of the Society that was held at Detroit in January is printed herewith. The authors were afforded an opportunity to submit written replies to points made in the discussion of the paper and the various discussers were provided with an edited transcript of their remarks for approval before publication. For the convenience of the members who desire to gather some knowledge of the subjects covered without referring to the complete text as originally printed in the February, 1927, issue of THE JOURNAL, *a brief abstract of the paper precedes the discussion.*

ABSTRACT

ALTHOUGH the enormous demand for automobiles has been met with continual improvement in performance, economy, comfort, and appearance of the vehicle, the development of the transmission has lagged badly for more than a decade. Car-ability has been handicapped by the limitations of the three-ratio gearbox. Notwithstanding that the added car-flexibility, economy and smoothness that result from increasing the number of ratios between the engine and the axle have long been appreciated by engineers, the shortcomings of conventional four-speed transmissions, friction drives and two-speed rear-axles having double ring-gears and pinions are many, and the first cost and lack of over-all efficiency of the gasoline-electric drive have prevented their greater use in passenger-car and truck service. The reasons for the failure of the present four-speed transmissions to give satisfaction are cited, and stress is laid on the need of reducing the maximum engine-speed while at the same time maintaining or improving the over-all car-ability.

A description is then given of a four-speed transmission by which the gasoline consumption, as indicated by road tests, is said to show a saving of approximately 20 per cent. The assembly consists essentially of a three-speed gearbox on the forward end of which is housed an internal-gear unit that provides a reduction of approximately 1.4 to 1.0 for the third-speed ratio. Shifting from third to fourth or from fourth to third is accomplished by a hollow metal-clutch, the tooth arrangement of which allows the maximum angular-motion of 40 deg. between the mating parts. The shift can, therefore, be made with ease regardless of the car speed. It is pointed out that this is of prime importance if the advantage of an additional ratio is to be realized. Tables and curves show the comparative performance of passenger-cars and trucks equipped with the four-speed internal-underdrive transmission and with the three-speed gearbox.

The conclusion is reached that, if no other advantage existed, the gasoline economy effected by the use of an additional gear-ratio would justify the expenditure of effort required to develop a successful product.

THE DISCUSSION

H. T. WOOLSON[3]:—The paper by Messrs. Neracher and Nutt on four-speed transmissions is to be commended as a very clear and concise presentation of a development that is of great interest to the industry at present.

The outstanding reason that a four-speed transmission has not previously been adopted in this Country is the fact that it has been impossible to obtain gears that will operate with sufficient quietness to suit the American public. The development of the internal type of gear with its quiet operation has made it possible to consider further the use of the four-speed transmission.

The effect of a suitable four-speed transmission will be a tendency to make engines smaller in size, or to allow material improvement in performance with the present engines.

In connection with the discussion as to the advantages or disadvantages of undergearing or overgearing, the engineering advantages all seem to be in favor of undergearing, in which the direct drive is on the fourth-speed. Greater efficiency can be expected, also less propeller-shaft whipping and balancing difficulties; and the bearings for the internal gear can be smaller because the period of loading is of much shorter duration and the gasoline economy is improved.

Although it is to be expected that the third-speed through internal gears will be used for city driving on account of better acceleration, there is no doubt that a great deal of city work will be in fourth-speed.

We see only one argument that can be advanced against the undergear idea of driving direct in fourth-speed; namely, the psychological effect in the mind of the buyer, owing to the fact that the American public has been educated to the idea of being able to negotiate all grades on the main highways on direct drive. In the overdrive design, an additional gear is provided in connection with the standard three-speed transmission, and the operation of this type is exactly that to which the driver has always been accustomed, the overspeed being used only on long drives when it is desired to reduce the speed of the engine; whereas, in the case of the four-speed or undergeared car, it is necessary to "sell" the driver on the

[1] Chief engineer, Durant Motors, Inc., Elizabeth, N. J.
[2] M.S.A.E.—Engineer, Durant Motors, Inc., Elizabeth, N. J.
[3] M.S.A.E.—Chief engineer, Chrysler Corporation, Detroit.

use of a speed additional to those to which he has been accustomed. It is believed, however, that the motorwise public can readily be sold on the undergeared type, in view of its superior engineering advantages.

F. C. THOMPSON[4]:—It is nothing more than natural that the trade should think that, as we are chain manufacturers, we are building four-speed chain transmissions. This is not true, although we began experimenting 10 years ago with four-speed chain transmission. After about 7 years, we decided that the chain transmission was both too heavy and too expensive to be commercial.

Three years ago, we stumbled on the idea of using internal and external gearing, getting the power back on the same shaft-center by using a double set of internal and external gears having the same basic principle as just discussed by Mr. Nutt. We have found this type of transmission very satisfactory.

After years of experimenting with four-speed transmissions, both chain and gear, we are sold on the overspeed rather than the underspeed type, which is contrary to the opinion of Mr. Nutt and his associates. We find that automobile engineers are divided in their opinions, about 50 per cent being in favor of the overspeed, and the other 50 per cent being in favor of the underspeed. In a short time, cars will be on the market, having four-speed transmissions, both direct on third and direct on fourth, one being the overspeed, the other the underspeed type; and we feel that the public will decide whether the future car will have the underspeed or the overspeed transmission.

We would warn the engineers against designing the transmission too small, as quietness is the important factor to be considered. The size of the internal and external gearing should not be sacrificed for the sake of weight, as small gears would be much noisier; and quietness is the important factor. The size of the shafts and bearings is also important, as rigidity is a factor in quietness. We all know that internal and external gearing can be made efficient and commercially quiet, if properly designed. If the transmission is designed too small and light, it will be noisy, and if the overspeed or underspeed is noisy, it will not be used by the driver except when the car cannot be operated otherwise. An attempt should not be made to crowd four speeds into the space occupied by the present three-speed transmission.

S. O. WHITE[5]:—One of the speakers in the Mystery Session stated that automotive design traveled in circles and gave some examples. This speaker did not say anything about the four-speed transmission, however. The idea of using a four-speed transmission with a fast rear-axle is not new. This particular application of internal gearing has possibly some new features and has completely changed the picture. We have come back to the starting-point of the same circle but are a little farther advanced.

I would recommend that the paper be given very careful study, particularly the diagrams, the features that are brought out, and the advantages of the geared third drive as compared with an overdrive. The overdrive was tried out years ago with four-speed transmissions.

The two things that we must keep in mind and emphasize are the necessity for at least a reasonable degree of quietness and an easy gearshift. The first thing that presents itself to prospective users is another shift. Two or three years ago, there was agitation for mechanical gearshifts, an effort to get away from shifting altogether, so that there is an obstacle to be overcome in telling persons they are to have more gearshifts. Therefore, some means of shifting or some method of design must be provided that will make the shifting easy, at least between the third and the fourth-speeds, so that the driver can accomplish it at any car speed. It is possible to shift from fourth to third-speed at 60 or 70 m.p.h. and back again. That is necessary in coasting down mountain roads. If a driver is using third-speed to hold the car back, goes into high, but finds he goes too fast, it may be a matter of life or death to be able to shift back into the lower gear-ratio. The two points, quietness of operation and ease of gear-shifting, must not be overlooked. A great many features have arisen in the course of this design that cannot be covered in a brief informal discussion. I can say that the statements made in the paper as to the quietness, efficiency and smoothness of operation of the car are not exaggerated at all. They are facts.

H. M. CRANE[6]:—Mr. Neracher was good enough to send me a copy of this paper more than a month ago and asked me to comment on it. I do not wish to go into points regarding details of design, but I will say in a general way that I like the whole tone of the paper and that I agree with it in all the main statements made. I think it may be interesting, however, for me to take advantage of my time in the automobile business, to go back possibly farther than many of the engineers present can go.

In the first place, it was mentioned in the paper that we have advanced far in car performance. That really is not the case. The 1908 Packard, in the standard condition of that time, and you realize that the standard car of 1908 was an open touring-car without starting, lighting and other things that have been added since, had fully the equivalent hill-climbing ability of 90 per cent of present day cars. About all that has been done in the last 15 or 20 years is to keep pace with the addition of weight to the car in the form of closed bodies, greater room, more accessories and more comfort, with ability to accelerate and to climb hills.

It always interests me to see a sudden discussion break out regarding some piece of motor-car apparatus that has a very long history. It may possibly indicate that someone has obtained a much newer and more wonderful device to do the work. On the other hand, it usually means that the conditions which made it desirable years ago and then apparently ceased to exist have again come to the front; and that is decidedly the case at present with regard to the four-speed transmission, whether it is produced in the way shown in the paper, or in some other way.

The reason is very simple. Any car in general use today requires that a certain maximum tractive effort be available at the rear wheels in case of emergency. It may not be needed on every car. It may be needed only once a year on some cars, but if you do not have it, you are gone. The result is that the multiplication between the engine and the rear wheels, coupled with the diameter of the wheels and the weight of the car, has a surprising degree of uniformity, depending on the use of the car.

I have made some rough figures that undoubtedly indicate that, if the engine torque at 1000 r.p.m., which, of course, is not the torque in starting but something

[4] M.S.A.E.—Manager of Detroit branch, Morse Chain Co., Detroit.

[5] M.S.A.E.—Chief engineer, Warner Gear Co., Muncie, Ind.

[6] M.S.A.E.—Technical assistant to the president, General Motors Corporation, New York City.

that is readily transferable from engine to engine, were brought to the rear wheel through the first speed in the gearbox, it would apparently work out that you would have about 2 lb. of tractive effort, maximum, for every 5 lb. of car-weight. I made this calculation in a great hurry, more or less in my head. I think you may be interested to check up on various commercial cars with a view to seeing whether there is not a great deal in it.

I do not think that this condition has changed at all in 20 years. Cars get into and must get out of just as difficult positions, in emergency grades to be climbed or bad conditions of sand, mud or snow, as they did 20 years ago. For that reason we have not been able to change the relations at the lower range of car performance.

On the other hand, if a man had come to you in 1910 and had said that he had driven 100 miles at a speed averaging more than 30 m.p.h., you would probably have classed him as a triple-coated liar. You were pretty sure that he had not checked his time when he started and that he probably returned at 2:00 o'clock, did not note the time until about 3:30, then remembered that he got in about 1:45.

Our experience as drivers indicated that, with road conditions as they were, an average of more than 30 m.p.h. could not be made for any length of time. You could do it only on short stretches. But the condition today is entirely reversed. You do not disbelieve a man now if he says that he has done so. In fact, it is easy to determine whether he has or has not, for all he has to do is to tell where he did it. An average of 35 or 40 m.p.h. for an hour can be made even in cars of very low cost. The high-priced cars are expected, of course, to do even more. That means that the upper range of engine-performance has been entirely changed in the last 20 years. Actually, most of the change has taken place since the World War on account of the enormous mileage of new roads over which high speed is possible.

This change has also affected the truck-makers, who, 15 or 20 years ago, as I recollect, used to discourse on the crazy ones who would ruin trucks by overspeeding. The truck-maker today who does not produce vehicles capable of 50 m.p.h. is losing business so fast that he can hardly keep one lap ahead of a receivership and is looking toward ruination. That means that truck design is more difficult because the multiplication required for emergencies and for digging out of holes must be greater on account of the greater weight of the vehicle in proportion to the size of the engine.

High-speed operation of even low-priced cars on the road has presented a definite problem. The paper has presented one solution of it. Another possible solution, which is worth a trial but is not a sure cure, is to increase engine size again to the point at which the engine speed is the average speed that the engine as commercially manufactured can maintain with satisfaction to the driver at the time, and afterward when he pays the repair bills.

I do not intend to start an argument for so-called slow-speed engines. I am merely saying that something can be done in that direction as well as in the direction indicated in the paper, always understanding that, by using a larger engine and maintaining a gear-ratio that will give the same ability, we cannot get the gasoline economy that can be obtained by using two high speeds in the gearbox, always provided that the owner will use the higher one most of the time. I believe that many owners will use it. I believe that every owner, who, for one reason or another, uses high road-speeds, will rapidly get into the habit of using the higher gear, whether it is a direct drive, as it may be, or an overgear.

The easier "feel" of the engine under those conditions will be sufficient to get him into the habit of using that gear at every opportunity. I say this because I came into the business at a time when the overgeared fourth-speed was fairly common, and I know that every man who had a car of that kind used the overgeared fourth-speed whenever he had a chance to make speed, although it was a spur-gear combination and created more or less noise.

The final thing I wish to say is that I am truly delighted to hear the strong words that have been said about the ease of shifting from third to fourth-speed. It is my greatest hope that the work put into this subject by the proponents of the dual high-speed gearbox will react on the design of three-speed gearboxes, because it is very necessary that it should. In some ways, it is the more necessary, because the three-speed gearbox today is used mostly as an emergency proposition, when the shift down must be made in a hurry and when the driver, if inexperienced, is liable to become confused. It is far too difficult to make; in fact, unnecessarily difficult.

The greatest surprise to me, in investigating European small cars, was to find that, in spite of the fact that shifting of gears is much more frequently necessary, the cheapest three-speed gearbox car produced in this Country today shifts gears far better and easier than any of the small cars made in either England or France that I have ever had an opportunity to drive.

P. L. TENNEY[7]:—In keeping with the apparently general movement of looking into four-speed transmissions, we have built and tried out both the overgeared and the direct fourth-speed drive, both in spur-gears and in internal gears. Our experience leads us unqualifiedly into agreement with the internal-gear transmission and the direct fourth. Mr. Neracher's paper has covered the subject wonderfully well and has gone into details in ways that we have not, but our experience checks his very closely.

I should like to bring out one point, however, with regard to the overgear and the undergear features and also the shift. Although it has been touched upon, I think I can make it clearer by reference to Fig. 1.

Starting with a 1-to-1 ratio at *a* we find that the axle ratios of small, medium-priced cars are grouped around 5 to 1. They range between 4.7 and 5.1 in practice, but in round numbers the average at present is 5 to 1. So in our figure we will put point *b* to represent high-gear with a three-speed transmission. Average second-gear and low-gear reductions are shown at *c* and *d* as 7.75 to 1 and 15 to 1, these being the averages of cars at present.

In putting an overgear on the same car we find that the different ratios range all the way between 3.80 and 4.25. We will show this as 4 to 1 on the second line of Fig. 1. We have added something to the original car, but have not helped position *b* at all. The present high-gear is a compromise, as we all know; it is as fast as we dare make it and get anywhere near enough acceleration, and as slow as we dare make it and have anywhere near enough speed on the open road.

I think we all will grant that if we can avoid this compromise we will have something else to work with in a four-speed transmission. We can split up that so-

[7] M.S.A.E.—Chief engineer, Muncie Products division of the General Motors Corporation, Muncie, Ind.

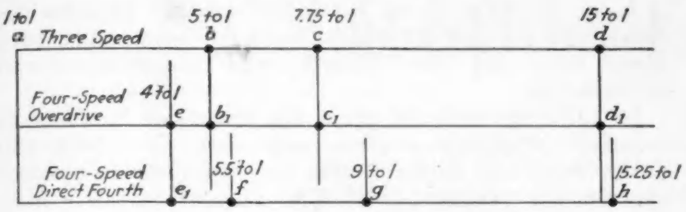


FIG. 1—COMPARATIVE DIAGRAM OF GEAR-RATIOS
Horizontal Distances on the Three Lines Represent Gear-Ratios. The Upper Line Is for a Three-Speed Transmission, the Second for a Transmission with Overgeared Fourth-Speed and the Lower for a Transmission with Direct Drive on Fourth-Speed

called high-gear. We will assume that in building the direct-fourth-speed drive, we put point e_1 in the third line in about the same place as point e in the second line. That is about where it will be used most of the time, very little over what the same car would do at top speed. It is possible that in the overgear it might be put up a very little higher if it is to be used purely as an open-road country-driving gear. The experience of several of us bears out the statement that fourth-speed is used right in traffic, and is used constantly.

With this gear reduction, we step the high gear down, from 33 to 38 per cent, which is more than we step the axle up, or, in round numbers, it gives an over-all gear-ratio of 5½ to 1, as indicated at f. Stepping the high gear down also permits lowering the second-gear ratio to about 9 to 1 shown at g. In our own work, we have reduced the low-gear ratio a trifle to 15¼ to 1 as shown at h, but this is not essential.

Those of you who have had, from Pittsburgh, Seattle, and other cities, continual complaints of low axle-ratio for hilly country can appreciate this. With a four-speed car, a fast axle, a lower third-speed ratio, and all that has been discussed in this paper, ease of shifting and quietness are accomplished. We will grant that it can be done commercially. For traffic work the gear-ratio is as low as is needed. Most of our cars start in intermediate. In boulevard and traffic work, 85 per cent of the cars are started in second gear. With the fourth-speed, there is a chance to revise ratios to better advantage. The acceleration of a 5½ to 1 axle can be obtained and, as soon as the car has been accelerated, even if you are going only to the corner at 20 m.p.h., you will use the fourth-gear, with the sensation of coasting. Above 32 or 35 m.p.h. the acceleration is faster in top speed than in third.

This arrangement gives the 4 to 1 direct performance that is used 90 per cent of the time, also the acceleration and hill-climbing ability of the 5½ to 1 axle. You who are familiar with the Uniontown, Pa., hill know how many cars can operate there in high-gear with 5 persons and touring baggage. Some cars can go over in high-gear with only 2 passengers. You can travel over any improved highway in the mountains in third-gear with the equivalent of a 5½ to 1 axle, whereas you cannot do so with a 5 to 1 axle. That solves the hill-climbing problem by giving the result of the axle ratio that is needed for performance, without being penalized as a car suitable only for a certain district or locality. The 4-to-1 ratio gives an advantage also over other cars on good roads.

We have determined that the question of shift is important by having people drive the car out without instruction. We feel that instead of adding an overgear, we have stepped up first, second and third gears, and added a new low-gear. That is the way the car is actually used. A four-speed car is driven in second, third and fourth-speeds instead of in first, second and third. We keep the shift standard to the extent shown in Fig. 2. The high should be where everybody is used to having it. Put it in right rear position. Put third, the next lower speed, in right forward position where it should be. The other speed that is constantly used is second. Put it in left rear position. As we have added an emergency low-gear it should be put in logical sequence, left front position. That crowds the reverse out of its place so we put it at the extreme left and rear, protected by a latch. The reason for putting it here is for convenience in passing from low to reverse and back again with the latch held up, so that the car can be "rocked" with this four-speed transmission when you get into mud, as easily as it can with the present three-speed transmission.

Several companies have brought out shifts with freak or at least special positions, possibly logical but contrary to custom. Until a person has been instructed and has acquired the habit of using them, these are very tricky. I have seen some funny things happen. We have built shifts both ways, so I am not talking entirely of the other fellow's product. In cars with shifts as shown in Fig. 2, laymen who have never driven a car with a fourth-speed are told to get in and drive, without instruction.

The motion is sufficiently logical so that no trouble is encountered. With some other shift arrangements quite different results have been experienced.

Preserving the shift to which we are accustomed with the advantages of a low axle-ratio there is no question but that this type of four-speed transmission can be of great help to car performance. The only economic advantages it possesses are some improvement in fuel economy and reduced wear on engine and propeller shaft, but when car performance, ability to climb, acceleration, and the smoothness we all have been waiting for are put into one combination, the transmission can be given a chance to do something instead of the engine doing all.

I have driven cars with high-geared axles and the standard three-speed transmission. For level country, a 4-to-1 axle and the standard three-speed transmission are all that are necessary until the car, in turning around

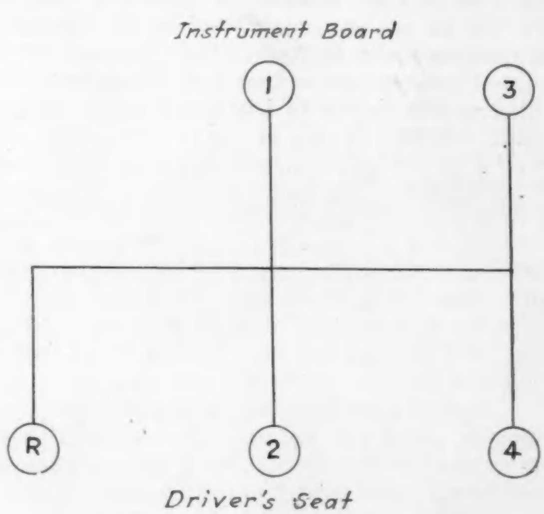


FIG. 2—GEARSHIFT POSITIONS FOR FOUR-SPEED TRANSMISSIONS
The Three Higher Speeds Are Placed in the Same Positions as the Forward Speeds of a Standard Three-Speed Shift, the Added Low-Gear Taking the Place of Reverse. A Latch Protects the Position of Reverse-Gear at the Left

on a paved road, gets into a ditch. When off the gravel road the low-speed cannot be spared. That is why the inclination is to consider this transmission as raising the normal speeds of the car and adding a new low-speed, although the top speed of the car is increased very little because the average performance of the engine will not pull it faster. By changing the gear-ratio an increase in the top speed of from 3 to 5 miles might be obtained, but the real difference is in the sensation of gliding, and it leaves no question as to the preference.

T. L. Fawick[8]:—A few years ago I began working out an internal-gear drive for motor-cars, being very desirous of getting something to reduce the engine speed when I wished to travel fast on country roads. This was accomplished by the single internal-gear and pinion, in which no idling gears were necessary in the third-speed and consequently no sound was produced in the high or third-speed by the idling gears. That worked out very well.

We also built a few jobs with the double internal-gear and pinion. That made a very good job, but I do not believe it is quite the thing unless it can be made absolutely quiet. I do not believe any car-owner would be satisfied with two high-gears, one for country driving and the other for city driving, unless both are absolutely quiet. I do not believe the future car having two high-ratios will work out any other way. The public will not accept a gear that is even slightly noisy in the third or fourth-speed. I think they both must be absolutely quiet. Of the gears we have produced, several thousand are driven through gears on the fourth-speed and direct on the third. We tried gearing some of the cars through the third and direct in fourth, but we found that, when driving along slowly, if any noise at all is made by the gear, it is made at the same time that the most sound comes from the engine. Of course, the present smooth-running engines cannot be heard much at 25 or 30 m.p.h., or whatever the lower speed happens to be. Consequently, if any sound at all is made by the transmission, it is very annoying, even though it is very little.

Although we have done a great deal of development work on internal gearing, what we are looking forward to for all motor vehicles is a job that will be absolutely quiet on the fourth as well as on the third-speed, or on the third as on the fourth.

Likewise, as has been mentioned by Mr. Neracher, the gears must be easily shifted. Of course that will follow. They must be arranged so that a shift can be made from the third or the fourth to any other speed without any difficulty.

[8] M.S.A.E.—Racine, Wis.

[9] M.S.A.E.—Field engineer, White Motor Co., Cleveland.

A. J. Scaife[9]:—I am interested in this problem because, for the last 17 years, we have been using both direct third and direct fourth-speed transmissions and still use them.

In 1910, we switched from the steam-car business to internal-combustion engines and have used both the direct third and direct fourth transmissions in passenger-cars and trucks. In Europe, they use a fairly high gear-ratio in the axle. In this Country we do everything in high.

When we began to make the 2-ton truck, for instance, we had a 7.5-to-1.0 axle-ratio, which gave 6.8 to 1.0 in the fourth-gear. It was our idea that, when the vehicle was loaded, the direct drive would be used and that the vehicle would return light in fourth gear. Although the fourth-gear was noisy, at that time we were not much worried about the noise. The most important thing was to do the work. In spite of that fact, the operator cannot be prevented from using high-gear. I have followed trucks loaded with coal, some of which carried 2 or 3 tons on a 2-ton truck, that were running in fourth-gear. The demand was for more power and we were forced to senger-car is simply a matter of properly proportioning in fourth-gear, the gear-ratio would be practically $7\frac{1}{2}$ to 1, or the same ratio that was used before in third-gear.

The gears were perfectly quiet in third-gear but drivers would run in fourth-gear, which was noisy, because it was high-gear.

Question:—The underdrive third-speed transmission apparently has been designed for passenger-car use, because of its quietness of operation. Would the greater efficiency of this type of gearing, as compared to the overdrive fourth-speed, warrant its added cost for truck use in which quietness is a minor factor?

Harold Nutt:—I do not know that it would. We have developed this type of transmission for six-cylinder speed trucks, in which the question of quietness of operation is of some moment. Referring to Mr. Scaife's comments, the probable reason that truck drivers continued to use the fourth-speed, even when the truck was loaded, was that they preferred to hear the howl of the gears than the rattle and roar of the engine. I think that the tendency to stay in high-gear is the same now as it has always been. In heavy-truck operation, quietness is not nearly so important as it is with fast light-trucks or passenger-cars.

Whether the unit is designed for a truck or for a passenger-car is simply a matter of properly proportioning the parts. We are working on a smaller, less costly transmission with the idea of ultimately making it adaptable to low-priced automobiles.

Scientific Transportation

By W. P. KELLETT[1]

Discussion of TRANSPORTATION AND SERVICE MEETING PAPER

THIS paper was presented at the Transportation and Service Meeting in Boston last November and was printed in full in the December, 1926, issue of THE JOURNAL. *The abstract printed herewith will refresh the memory of those who have read the paper. The discussion following is valuable because it gives the viewpoints of important railroad officials and experts who deal with transportation both by rail and by highway, as well as the views of automotive transportation engineers.*

ABSTRACT

IN an expedited store-door freight-service, such as obtains in Great Britain, the railroads assume full responsibility for the complete transportation of merchandise freight from the door of the consignor to the door of the consignee. In the American system, the railroads assume responsibility for its movement from station to station only. To the persistent refusal by the railroads of this Country to meet the demands of the public for expansion of the service to include collection and delivery of merchandise can be traced the growth of motor-truck freight-haulage in competition with the railroads. But each of these transportation mediums possesses its greatest strength where the other displays its greatest weakness; consequently, they present an ideal basis for coordination of service along rational lines.

Store-door collection and delivery service is an integral part of a coordinated system and, as a means of reducing the number of handlings of freight necessary by present methods, the use of the container system is receiving increased attention. Among the salient features that such a system should possess are simplicity, ability to load and unload with the same ease and by the same means as are now employed in loading standard railroad equipment, capacity for transferring the containers quickly and easily from the car to the truck chassis without the use of special equipment, and sturdiness and strength to withstand shocks. A description of such a system is given, special attention being devoted to methods of loading and unloading the containers, the cost of transfer, the manner of operation of containers, their economic range of usefulness, the expansion of terminal facilities, the classes of freight best adapted to shipment by containers, and the principal obstacles to be overcome in the introduction of the container system.

THE DISCUSSION

W. R. GORDON[2]:—Mr. Kellett enunciated one of the fundamentals of transportation as road haul at the lowest possible cost per ton-mile. He will agree with me in supplementing that statement with another, namely, that it should be done in the least possible time, which is also fundamental. Mr. Kellett's paper opens up an entirely new field, a sort of intermediate between truck and railroad transportation. One can very well supplement the other, to the detriment of neither, and can reduce the cost of operation considerably. It seems to me, however, that a very considerable outlay in special equipment would be necessary, that the buildings would have to be worked out especially for that purpose, with consideration of railroad tracks, platform heights and so on. The question of the saving in operation is problematical. Roughly, I should say that, on distances of more than 100 miles, the operation might show a saving. The investment in special equipment is large and must be justified. The equipment is highly specialized; it is different from truck equipment that already has a large field of operation and can be adapted to one job or another. The container would have to handle a very restricted type of freight that is suited to it. The cost and the weight are also involved, particularly when the container is carried on the truck chassis.

W. P. KELLETT:—I do not agree that containers could handle only a restricted class of freight. Almost the entire production of Great Britain is handled in railroad cars of but little greater cubic or tonnage-capacity than the containers I have described.

The freight offered for transportation in this Country is very similar in character to that transported by the railroads of Great Britain, but our average rail-haul is about 12 times greater. It is our long hauls and not any essential difference in the character of freight we transport that has been responsible for the development of our large-capacity freight-car.

A. J. SCAIFE[3]:—Have containers been tried out in actual service on any railroad or in any way, small or large?

MR. KELLETT:—The system of transportation I have described is purely theoretical. So far as I know it has not been tried out except that the furniture van has been a factor in British transportation service for many years.

The system I have outlined is a combination of the British method of transporting furniture and the American circus method of end loading and unloading, a system the circuses have used continuously for more than a quarter of a century. In my opinion this is the most economical and most efficient method yet devised for loading and unloading miscellaneous freight.

MR. GORDON:—Over what operating distance would you consider the container system to have an advantage in comparison with the truck, over distances of more than 25 miles?

MR. KELLETT:—I believe that a saving could be shown over a distance of 15 miles. The cost of transferring the containers from truck to car is very small.

MR. GORDON:—I can see that it would have an advan-

[1] Consulting engineer, Brantford, Ont., Canada.

[2] M.S.A.E.—Sales engineer, Pierce Arrow Motor Car Co., Buffalo.

[3] M.S.A.E.—Field engineer, White Motor Co., Cleveland.

tage in the packing of the container, in cheaper insurance rates, and, perhaps, in less damage to freight.

MR. KELLETT:—That goes without saying, because that is what the truck has done. In transporting by motor-truck, the pilferage and damage are much less than in transporting by rail.

MR. GORDON:—The system is essentially for use by the railroad companies.

MR. KELLETT:—Yes. It is a system that will enable the railroads to engage in through transportation from consignor to consignee. They have never been in that business yet in the United States except in one or two isolated cases.

QUESTION:—Does the container always ride on its own casters?

MR. KELLETT:—Yes.

J. W. FOOTE[4]:—I understood Mr. Kellett to say that there is an insistent demand for store-door delivery by the public at large. Our information, based upon a questionnaire sent to shippers and merchants in New York City, is that the demand for store-door delivery is negligible. Shippers and consignees, at least in New York City, seem satisfied with their present trucking arrangements.

MR. KELLETT:—During the last 3 years we have seen a tremendous growth in motor-truck transportation in this Country in direct competition with the service offered by the railroads. In my opinion the factors responsible for the rapid growth of this competing facility is its ability to offer store-door express service at substantially freight rates.

B. F. FITCH[5]:—Your program is predicated on the idea that all freight-station platforms will be at the same elevation as the special railroad-car platforms, is it not?

MR. KELLETT:—Yes.

MR. FITCH:—That involves, then, new rolling-stock equipment for the railroads at capital expense plus capital expense for revision of the platforms at nearly all existing stations.

MR. KELLETT:—Proper facilities would have to be provided at terminal and zone points.

MR. FITCH:—How about local way-points?

MR. KELLETT:—Service between way points and nearest zone stations would be performed by motor-truck.

MR. FITCH:—As I understood from your description, the trucks would have certain junction points with the railroads at which the loaded containers having the pick-up of local freight would be transferred to the flat-car for the long-haul rail movement, and vice-versa for delivery. How would you perform that service between the truck and the car?

MR. KELLETT:—Special facilities would be required at all terminal and zone points. As I have said before, this system cannot be introduced as a wholesale innovation. It must first be introduced as a purely local movement. When connecting railroads see its advantages they will adopt it, and after a while it will become universal.

MR. FITCH:—I think the container will become universal. I fully endorse your program, with two exceptions. One is that anything that is done with containers must be at the minimum capital expense to the carriers. If any program is proposed that involves huge capital expense, I do not think that anything can be accomplished. The idea is to have the container adopted in the easiest way possible. I think you advocated the interchange of these containers without expense for cranes and craneways. We have found from experience that in 32 freight-stations there is absolutely no standardization. I have inspected over 2000 freight-stations in the United States and have yet to see similarity between any two stations. To begin with, the platform elevations vary from street level to 54 in. The platform elevations cannot be changed without changing the rail grades or the street grades. No long platform has the same elevation at both ends, because of grades for drainage of the abutting streets. Therefore special provision or changes must be made in the platforms at every freight-station. That certainly runs into greater capital expense than the small item of investment in cranes and craneways that you criticize.

MR. KELLETT:—The question of capital expenditure is important, but we must remember this: If the railroads of this Country expect to give efficient transportation service at reasonable rates they must provide the necessary facilities. Until they do so they will never eliminate motor-truck competition.

L. R. GWYN, JR.[6]:—For transporting the containers do you propose to use flat-cars of the type known as "passenger-train equipped," or will they be the ordinary railroad flat-cars with cast-iron wheels? Express for the most part is moving at passenger-train speed and on passenger-train schedules. I do not believe that could be done with freight equipment.

MR. KELLETT:—I do not see why passenger-type cars should be required for moving freight at 40 m.p.h.

MR. GWYN:—A great deal of our express matter must go faster than 40 m.p.h.

MR. KELLETT:—I think it is safe to say that the motor-truck will continue to compete successfully for short-haul traffic until the railroads offer a better service for less money, a service that is, in my opinion, entirely possible by the use of properly designed container equipment. However, any service capable of eliminating motor-truck competition will in all probability be equally effective in absorbing much of the short-haul traffic now handled by the express companies, a class of business that the railroads could not handle profitably at freight rates. The remedy for this would appear to be the classification of all small consignments under a certain minimum weight as Class-B express to be handled exclusively by the express companies on the same fast freight trains which carry other container freight.

The rates applying would of course have to be approved by the Interstate Commerce Commission. If they were too high the business would revert to the motor-truck, consequently there would be no possibility of maintaining a rate schedule higher than the cost of the service warranted.

QUESTION:—How are the doors made water-tight?

MR. KELLETT:—I did not go into that detail. I suppose they can be made water-tight. The containers have two side-doors and one end-door. The equipment, as I have designed it, has just the ordinary box-car-type door.

CHAIRMAN F. C. HORNER[7]:—How do you get from one container to another on trucks?

MR. KELLETT:—Containers are on caster wheels and can be swung around in any direction. Only one container is carried on each motor-truck chassis, not two.

CHAIRMAN HORNER:—How does the caster work, does it lock and swivel?

[4] Transportation inspector, New York Central Railway, New York City.

[5] A.S.A.E.—President, Motor Terminal Co., 25 Broadway, New York City.

[6] Jun. S.A.E.—Assistant superintendent of the motor-vehicle department, American Railway Express Co., Brooklyn, N. Y.

[7] M.S.A.E.—Assistant to the vice-president, General Motors Corporation, New York City.

MR. KELLETT:—Caster wheels swivel but do not lock.

R. S. WOODBERRY[8]:—If it does not lock, how will you handle it on a freight-house platform? The front wheels must swivel and the rear wheels must be locked to handle the container on the platform so it will move in a straight line.

MR. KELLETT:—Front and rear wheels swivel 45 deg. in either direction and are cross connected by rods coupled to a draw-bar. Containers can be steered from either end, and front or rear wheels may be locked in forward-running position by inserting a pin locking the draw-bar in center position. Intermediate wheels are of the caster type and are free to assume any position to adapt themselves to the direction in which the container is being moved. It has not been possible to show these minor details on the small-scale drawings used to illustrate the system.

CHAIRMAN HORNER:—On what kind of floor can one man handle a loaded 5-ton container?

MR. KELLETT:—On a smooth-surfaced cement floor. I personally have handled one of Mr. Perin's containers that was said to contain 4 tons. It did not require much effort to handle it.

MR. WOODBERRY:—I am handling those same containers every day. Four men are needed to handle a loaded 5-ton container on a cement floor.

CHAIRMAN HORNER:—How do you get the truck level with the platform?

MR. KELLETT:—All trucks and trailers used should be equipped with elevating and dumping mechanism, to facilitate unloading of gondola-type containers and to provide for the varying heights of platforms and warehouse floors. All freight-car decks are practically the same height. There may be a difference of 2 or 3 in. but not more. The street level could be maintained at an elevation which would bring the truck bed level with the platform without having to use the elevating-gear.

MR. WOODBERRY:—When a truck is loaded with a container it would not meet the platform level because of a spring deflection of from 3 to 4 in.

MR. KELLETT:—That is taken care of by a wedge on the rear end of the truck chassis.

MR. SCAIFE:—Why are casters used? At the warehouse, a roller bed with casters could be used, and truck bed and the car bed could have rollers.

MR. KELLETT:—Experience must prove whether rollers on the car or casters under the containers are better. I am told that casters are entirely practical.

C. S. LAKE[9]:—Railroads generally have had some experience with containers but I question seriously whether many of their representatives know or have thought much about them.

While we are approaching a point of understanding, several statements that have been made with the kindest purpose are misleading. Since the railroad man, the manufacturer, the truck operator, the theorist, the engineer, each thinks he knows the most about his business, a little explanation is befitting. Mr. Kellett stated that at one time the railroads of this Country had not given transportation. I take exception to that statement, with all due respect to Mr. Kellett. The railroads have been giving transportation to this Country, but, of course, the transportation that they gave 50 years ago would not suffice for the conditions that they meet today. The railroads in the past have not adopted, and they cannot at any time in the future adopt, a system on which they can rest for all time. On the contrary, they must be progressive and must avail themselves of the cooperation and the education that they derive from suggestions such as we have heard this morning, and as we hear on many other such occasions. I do not think it can be fairly stated that the railroads of this Country are today opposing any progressive transportation movement. If they are, I am unaware of it. I am sure the railroad with which I am identified has never opposed the introduction of the motorcoach, the inland waterway or anything else that is good for the community that we serve. We believe, generally speaking, that whatever is good for the community must eventually be good for our interest as well, because we are a part of the community. In other words, we believe that in this great Country there is room for all the modes of transportation that have thus far been developed. The fact that some railroad men are here today as your guests is the best evidence of their desire to affiliate with you in so far as they reasonably can to have at least the benefit of the information that you can tender them and to coordinate and cooperate with you in every consistent way.

I believe that while we see an enormous revolution of business in this Country, when the present is compared with the last 20 or 30 years, we are still in our infancy. I think there is no question about that. The time is ripe for the leaders of every transportation movement to know each other better and to respect each other's intentions, coordinating for the common weal.

Because of the intricacy of their business it has taken the railroads 100 years to reach a systematic standard that the public will understand and endorse. The railroads today are a unit in their methods. They carry on, report and account for their transactions in a uniform manner, under the regulation of a governmental body. The motor-truck companies have not yet had that opportunity. They have come into existence largely as a matter of circumstances. They have not yet had the opportunity to get together and systematize their activities and put themselves on a uniform basis of operation, reporting, accounting, and such as the railroads have; but I anticipate that the time is not far distant when they will have accomplished that. I am happy to be among the great number of forward-looking men who are endeavoring to find a way to please the public in all its requirements.

CHAIRMAN HORNER:—Mr. Hardy said[10], speaking for transportation men and railroad men generally, that we must think of the public interest. Mr. Lake has echoed that sentiment. There is no question that we must serve the public in a reasonable way, consistent with a fair profit in our business. If we, as railroad men or motor-truck or motorcoach operators or whatever we may be, do not, somebody else will. The sooner we all forget that we are steam-railroad, electric-railway or motor-truck men, and begin to realize that we are transportation men, the sooner we shall progress.

With reference to the theorists, I think Mr. Lake and all those present will agree with me that, without theory, there is no practice; an idea that seems wild today may be a very tangible, practical proposal next year, or perhaps next week, in an exceptional case.

I noticed with much interest what Mr. Lake said about the railroads not opposing the onward march of the motor-vehicle. Within the last 4 or 5 years I have been in

[8] General manager and treasurer, Freight Container Service Co., Boston.

[9] Assistant to the president, Chesapeake & Ohio Railway Co., Richmond, Va.

[10] See p. 44.

contact with practically every railroad official east of the Mississippi River who deals definitely with the traffic and operating problems of his road and with this question of the motor-vehicle, and I should like to be able to corroborate that statement; but even though one may not oppose a thing, one can by a constant system of watchful waiting retard the progress of a program very materially. I think the picture is changing, however, in spite of the fact that there are a great many die-hards in both the railroad and the road-transport fraternities, men who will not see the light far enough to realize that the railroad man has problems that the motor-transport man does not now understand and comprehend but must before he can be of real service to the railroad man. I think definite progress is being made. I should like to see that progress go forward at a little faster pace, and I think it is speeding up constantly.

I was very much interested in what Mr. Lake said about the railroads working as a unit. My observations lead me to believe that this has in many instances retarded the progress of the use of motor-vehicles by the railroads and the electric railways of this Country, when they could progress to advantage. I for one am not trying to show the railroads where they can use the motor-vehicle to disadvantage, only to advantage; but when the unit rule is carried out, it often happens that railroad executives confer with one another regarding a problem that is common to them all and, because the consensus of opinion is to the effect that they should put the soft pedal on it for the moment, the railroad that is most keenly interested and perhaps would obtain the greatest advantage decides to wait. I hope that this custom will change and that, when it is an incontrovertible fact that an individual railroad can apply the motor-vehicle to advantage, that railroad will act individually. I think the trend is in that direction.

MR. LAKE:—I would like to correct an apparent misunderstanding on your part. When I referred to the railroads acting as a unit, I meant with reference to the uniform method of conducting their business and of reporting it to the Government of the United States and to the public. I did not mean with respect to the introduction of, or their attitude toward, motor transport. The fact is, that in connection with the introduction of motor transport, each railroad executive is exercising his own individual initiative and point of view. Thus far there is no definite concerted movement that might be regarded as a unit movement in that respect except this: Some months ago, the railroads thought enough of the motor-transport business to create a merely temporary organization known as Railroad Motor-Transport Conference. It was instituted for the purpose of trying to interest all the railroads of the United States and Canada in the advisability of a permanent organization to look into all phases of this question. I might say that this temporary organization is making considerable progress. So far its endeavors have been wholly educational. It has merely been trying to ascertain something about the new form of transportation, about which it asserts that it knows nothing.

CHAIRMAN HORNER:—I have learned of the progress of the Railroad Motor-Transport Conference through the press and railroad publications, and I think it is a most meritorious movement on the part of the railroad men dealing with motor-vehicle problems. It will be, just as this meeting has been, instrumental in bringing about a thorough ventilation of the views that we as individuals have on these various problems.

It is conducted, I understand, in more or less of a star-chamber manner. In one way this is probably a good idea, for you can speak frankly to one another about the various problems and the various types of equipment you are using and can compare notes. Later on I hope it will be found advisable for you to call in those who are experienced in the application of the motor-vehicle, both the motorcoach and the motor-truck, to confer with you on your various passenger and freight haulage problems. There is no question that you can learn from the experience of those who have been working on the problems of road-transport operation for so long, as they also can learn from you.

MR. LAKE:—I concur in that view. In the event the railroads at large ever reach the stage where a permanent organization is adopted, I concur that we should have the expert advice of those who are more familiar with highway operation than we are.

N. D. BALLENTINE[11]:—I wish to support what Mr. Lake has said about the intention of the railroads generally to cooperate and coordinate with this Society. To my mind, one of the things that the railroads need most throughout their business is more detailed information with respect to what is happening. As I have studied the motorcoach and motor-truck question, I have been impressed with the fact that there is a dearth of real information about the cost of operation and of maintenance of motorcoaches. I was very glad to hear one of the speakers indicate that he had a definite line of information. That is essential, but it seems to me that the Society could, with profit to itself and to the carriers, undertake to outline the kind of information that is vital, to determine what is an efficient machine, and for the carriers to develop certain detailed information. That is just as essential.

In dealing with transportation, ton-miles or passenger-miles are vital. Most of the data with respect to truck or motorcoach operation have not that essential detail. I am a member of the Railroad Motor-Transport Conference, and as such have hoped that we would be able to cooperate and coordinate with an association such as the Society with the idea that we would each prepare certain fundamental information.

If one can get the facts, it does not take a great deal of study to determine what is the right thing to do. We must, in the final analysis, give to the public the most economical form of transportation, whether it is rail, motor or air service.

Regarding containers I have had no personal experience, but one vital point seems to need careful consideration. I do not think that it has been mentioned. The trend of traffic in the United States is largely eastbound. The producing section is in the West, the net result being that two loaded cars move East to one loaded car that moves West. That means that the utilization of empty westbound box-cars is important. The more empty cars that can be utilized in westbound loading, the more economical will be rail transportation.

Balanced traffic produces an ideal condition. An increase in the kinds of transportation equipment is a serious problem. What is needed is more uniform equipment, not greater complexity of units. If containers are loaded westbound on specially equipped cars, they must be collected and returned to the East. Eastbound is the prevailing direction of traffic. If special equipment is needed to bring the containers eastbound, a cost

[11] Assistant to the president, Seaboard Air Line Railway, Baltimore.

of transportation is injected that must be reckoned with in the final analysis as to whether containers are economical on long-haul traffic. To my mind that is a very important consideration.

F. J. SCARR[12]:—Mr. Ballentine referred to loaded cars moving East and West. Does that same proportion apply to less-than-carload shipments?

MR. BALLENTINE:—The general trend of jobbing or less-than-carload traffic is westbound, in the direction of the movement of empty box cars. I have had some experience in nearly all parts of the Country and know that Chicago jobs West and Missouri River points job West. In other words, the carriers of westbound merchandise have westbound peddler-cars and through-merchandise cars. The eastbound less-than-carload shipments are relatively few.

MR. SCARR:—Do you know the proportion?

MR. BALLENTINE:—I should say roughly, 4 to 1, that is, 4 cars of merchandise westbound to 1 eastbound; but I know, as an officer of several of the trunk lines, that the protection of eastbound merchandise traffic is not a problem at all, it is the westbound traffic that troubles.

About loaded cars of less-than-carload traffic westbound, we often hear a statement that tons per car are wanted, and it may interest you to know that every other time we load a box car in the United States, we put an average of 7 tons of freight into it. The weight of the car is three times as much as that of the contents.

Frequently, it is economical for an east and west line, or a north and south line, to put less than 7 tons of freight into a merchandise car if it is moving into territory where your equipment is needed. Many times on the Union Pacific Railroad, where I was transportation officer for a number of years, we put 2 or 3 tons instead of 5, 7 or 8 tons into a car, and sent it into the grain-loading territory. When the merchandise is unloaded we have not delayed the local crew in unloading and have spotted the car for its return load of grain. This is an economic consideration that is vital to any study of the container problem on long hauls.

A. HATTON[13]:—Railroad companies aim to serve the public and to earn a fair return for the owners of the property. We are improving our service daily but are not perfect. There is always room for further improvement and we are ready to take up anything in the way of other agencies or methods that will help our service. Naturally, the expense of an innovation has to be considered. Concerning the container car; just what is to be done with mixed shipments like cheese and butter, paints and oils, and with merchandise going to one consignee or to one destination?

MR. WOODBERRY:—Exactly the same as in a box car. They must be segregated. One has a better chance to do so than in a box car because the containers carry only from 4 to 5 tons each and perishable goods or goods that take an odor are kept in one container.

CHAIRMAN HORNER:—What do you mean by perishable?

MR. WOODBERRY:—Eggs, fruit, anything of a perishable nature. The goods shipped by chain stores all go in one container to one store, there being nothing that will damage other articles.

CHAIRMAN HORNER:—Do you refer to semi-perishable fruits, such as citrus fruits, apples and so on? You would not pack peaches and watermelons in containers.

MR. WOODBERRY:—Watermelons are put in one container, loose.

CHAIRMAN HORNER:—What about peaches?

MR. WOODBERRY:—They are moved in their own baskets with other freight in motor-trucks or in box cars. They will receive better attention in containers than they receive in box cars.

M. F. STEINBERGER[14]:—Each plan for using containers seems to hinge on store-door delivery. It is not certain that store-door delivery is really desired in this Country. Mr. Fitch has indicated the result of a questionnaire sent out by the Merchants Association of New York City. If I remember the figures correctly, 11,000 questionnaires were sent out and 40 replies were received. That does not indicate a very widespread interest in store-door delivery. I have been told by Mr. Woodruff, of the New York Central Railroad, that an agitation has been begun in England to abolish store-door delivery, but I cannot vouch for that statement.

A speaker in another session made the statement that motor-truck salesmen endeavor to sell trucks rather than transportation. I might illustrate that by citing something that occurred to me several years ago. A representative of a motor-truck company who was making a survey of the railroads worked out an elaborate plan for handling less-than-carload traffic by motor-trucks.

I said, "That is very well, we can do that, but what shall we do with the local freight-train?"

He intimated that that was my job. He did not care what we did with it. It is true that we could have handled the less-than-carload freight with motor-trucks, but that would not have eliminated the local freight-train, because our policy, like that of several other railroads, is to operate one train for both package and less-than-carload freight. When the less-than-carload traffic is eliminated from the local train, it must still be run to handle the switching, so that only 1 or 2 hr. overtime may be saved if the less-than-carload freight is handled by motor-trucks, and that is not enough to justify their use. Some of the officers of our railroad are pretty "hard-boiled" and must be shown that it will mean money in the treasury before they will adopt a new plan.

I have been an advocate of motor-trucks and motorcoaches for the last 2 or 3 years, but motor-truck and motorcoach salesmen do not always get the attitude of the railroads on these problems.

With regard to store-door delivery, it is probably a fact that any shipper or any consignee of freight who really wants store-door delivery in this Country can get it today. There is no city or town in the United States that does not have a reasonably responsible trucking-service. In Baltimore, to cite an illustration, the Baltimore & Ohio Railroad operates a subsidiary company known as the Blue Line Transfer. Eighty-five per cent of its business is store-door, but it is handled through direct negotiation with the shipper or consignee. In other words, consignees who use that service order the freight agent to turn over the arrival notice of the freight and the freight itself to the Blue Line Transfer which, in turn, delivers it without further question. I think there are companies that will give the same kind of service in every reasonably large city or town in this Country, it it is desired.

Certain newspapers have recently been filled with criticisms of the railroads because they do not adopt the

(Concluded on p. 106)

12 Supervisor of motor service, Pennsylvania Railroad, Philadelphia.

13 General superintendent of transportation, Canadian Pacific Railway, Montreal, Que., Canada.

14 Special engineer, Baltimore & Ohio Railroad, Baltimore.

Efficiency Test for Radiator-Fan-Type Air-Cleaners

By A. H. HOFFMAN[1]

NORTHERN CALIFORNIA SECTION PAPER *Illustrated with* DRAWINGS, PHOTOGRAPHS AND CHART

ABSTRACT

SINCE air-cleaners of the radiator-fan type cannot be tested satisfactorily by the older method, in which a known weight of dust is fed directly into the airstream entering the air-cleaner, a special method was found necessary in which the air-cleaner under test is mounted in its normal position behind a radiator fan that is located inside of an elliptical wind-tunnel within which the fan circulates air. A tractor engine running at constant speed and load drives the fan in the wind-tunnel and draws the air for its carbureter from the wind-tunnel through the air-cleaner under test and an absolute air-cleaner connected in series.

A 100-gram charge of a standardized dust is introduced into the wind-tunnel. By averaging the results obtained from repeated tests, using three different collecting-type dry centrifugal air-cleaners, it is found that under normal conditions 15 per cent of the total dust-charge actually reaches the air-cleaner under test in the described apparatus. Therefore, 15 grams is the basis on which the efficiencies of dust separation are calculated. With one exception, the air-cleaners tested showed rather low efficiency. The vacuum or restriction effects, measured by the usual open U-tube manometer, were found low and were unaffected by accumulation of dust except in the case of two air-cleaners. The test method and the apparatus described can be used to test air-cleaners of practically any type, but the accuracy is less than that of the older method. Descriptions of the air-cleaners, tables of summarized data, and numerous observations are presented.

SINCE 1923, a number of air-cleaners that use the blast from the radiator fan as an auxiliary have come on the market. Some of these, because of their compactness, simplicity and small maintenance-requirement, seem admirably adapted for use on automobiles; hence, it has become necessary to find out how efficiently they remove the dust from the air and how great their vacuum or restriction effect is. The latter effect can be determined easily by means of an ordinary U-tube manometer and a piezometer ring properly applied and connected. Determination of the efficiency of dust separation entails more difficulty. The test method[2] of 1922, in which a standard quantity of dust was fed directly into the airstream entering the air-cleaner under test was inapplicable, because it was found impossible to determine with any fair degree of accuracy what percentage of a standard dust-sample sent through a radiator and fan actually would reach the air-cleaner in its normal position under the hood of an automobile. Under such conditions, the effects of slight air-currents were found too great for reliable results. Reference is made also to the 1924 California Air-Cleaner Tests[3].

METHOD OF DETERMINING EFFICIENCY[4]

The air-cleaner undergoing test is mounted in a standard position in the blast of a radiator fan within an enclosed space. Through the air-cleaner is drawn the air for the carbureter of an engine running at specified speed and load. The fan is belt-driven from the engine at suitable speeds. A given quantity of a standardized dust is introduced into the enclosed space by a process producing a fine-dust cloud. What portion of the introduced charge of dust actually reaches the intake of the air-cleaner is determined by appropriate means. The dust not removed from the air in its passage through the air-cleaner undergoing test is caught by a so-called absolute air-cleaner and its quantity is determined. The dust-separation efficiency is the quotient that arises

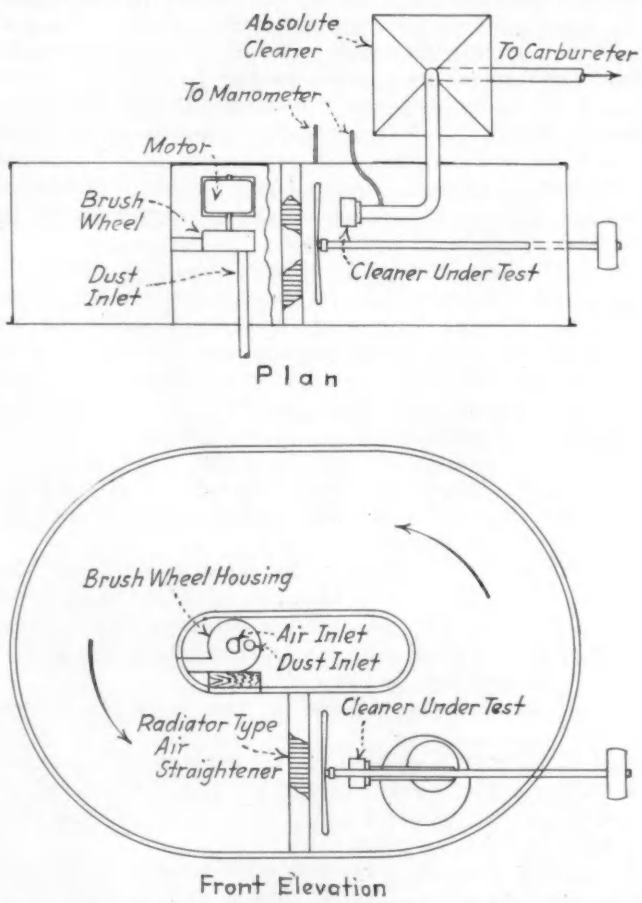


FIG. 1—EFFICIENCY-TESTING APPARATUS FOR RADIATOR-FAN-TYPE AIR-CLEANERS

The Air-Cleaner Is Placed in Its Regular Position behind the Radiator Fan. Air for the Carbureter of an Engine Is Drawn through the Air-Cleaner from an Oval Wind-Tunnel into Which Dust Is Introduced. An "Absolute Air-Cleaner" Catches the Dust Not Stopped by the Air-Cleaner Undergoing Test

[1] Agricultural engineering division, University of California, Davis, Cal.

[2] See *Agricultural Engineering*, June, 1923, p. 89; July, 1923, p. 109.

[3] See THE JOURNAL, March, 1925, p. 367.

[4] The method and the apparatus described follow in part a suggestion of H. G. Kamrath, formerly of the General Motors Corporation, Detroit.

when the weight of dust removed by the air-cleaner under test is divided by the weight of dust actually reaching the intake of the air-cleaner.

Description of Test Apparatus

The air-cleaner undergoing test is placed in its normal working-position behind the six-bladed 17-in. diameter fan of a well-known make of automobile. The standard test-position, as arbitrarily chosen, is with the effective center of the inlet of the air-cleaner A in the horizontal plane of the fan-shaft, 6½ in. from the fan-shaft axis and 6½ in. back from the plane of the front edges of the fan B, as indicated in Figs. 1 and 2. Ahead of the fan B is an air-straightener C in the shape of a radiator made up of straight horizontal open tubes of ¾ x ¾-in. section. Air-cleaner, fan and air-straightener are mounted inside of an elliptical ring-shaped wind-tunnel 5 x 7 ft. outside and 2 x 2-ft. section of air-path, placed with its short-diameter axis vertical. The fan B is mounted on

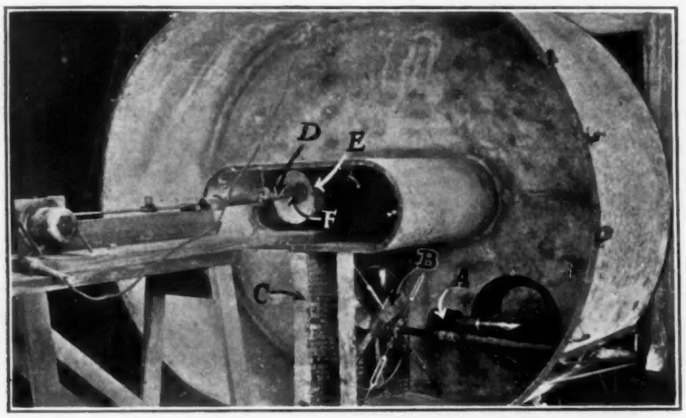


Fig. 2—Interior of the Testing Apparatus with the Cover Removed

An Air-Cleaner in the Standard Test-Position Is Shown at A; the Radiator Fan of a Popular Make of Automobile Is Located at B; an Air-Straightener To Rectify Cross-Currents Appears at C; the Dust-Feed Tube with Motor-Driven Plunger Is at D; the Housing for the Revolving Bristle-Brush Is at E; and the Air-Inlet Is at F

a shaft projecting to the outside of the wind-tunnel wall and is belt-driven from a Weidely Model MAU tractor engine. Driven pulleys of different sizes are used to give three fan-speeds; low 660, medium 1208 to 1220, and high, 1630 r.p.m. These correspond to wind-speeds of 1180, 2150 to 2175, and 2900 ft. per min. Fig. 3 shows wind-speeds found under the hoods of several automobiles. The engine in all the tests is run at 1200 r.p.m. with a brake load of 20.4 hp., the quantity of air entering the carbureter being approximately 50 cu. ft. per min. Air enters the wind-tunnel through a dust-feeding mechanism indicated in Fig. 4, which consists of a rapidly revolving bristle-brush in a sheet-metal housing. The work of the revolving bristle-brush is two-fold; to act as a supercharger that overcomes air-friction effects and maintains atmospheric pressure inside the wind-tunnel, and to brush-out the ingoing dust-sample into approximately as fine division as would be encountered on the road.

Kind of Dust Used

The dust used is uniform and composite and is obtained by air-elutriation from soil-samples taken from fields in 10 different parts of California. When weighed-out, the 100-gram charges of dust are not completely dry but contain 3.2 per cent of hygroscopic moisture. However, all subsequent weighings are necessarily on a dry

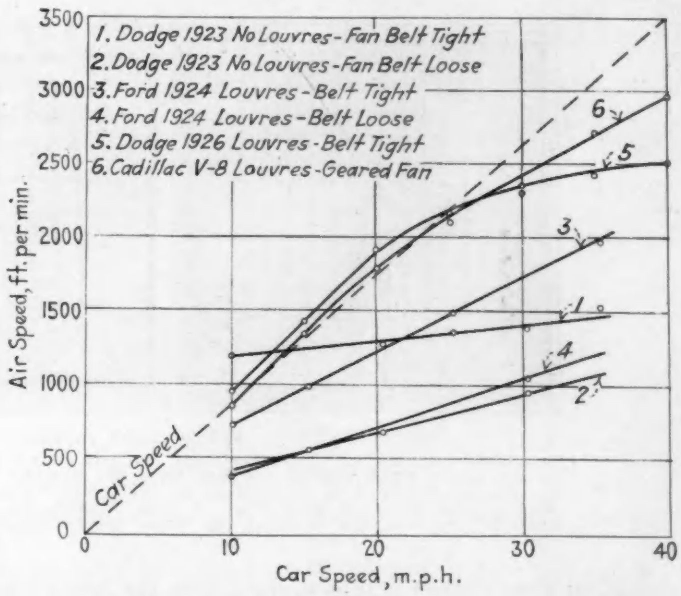


Fig. 3—Chart Showing Wind-Speeds under the Hoods of Automobiles

An Anemometer Is Placed Directly Back of the Fan. Tests Were Made in Calm Weather. Each Point Shown Is the Average of Two Successive Tests Run, One to the East and One to the West

basis to avoid errors that would be caused by varying atmospheric humidity. Of each charge of dust, only 15 grams actually reaches the air-cleaner undergoing test. This factor was obtained by running repeated tests on three different dry centrifugal air-cleaners that collect the dust they remove from the air. Table 1 gives calibration data for the testing apparatus and affords means for estimating the probable error inherent in the method. It is included so that some idea may be had of the variations encountered.

Method of Dust-Feeding

The 100-gram charge of dust is placed in a cylindrical tube. A plunger operated by a motor through a speed-

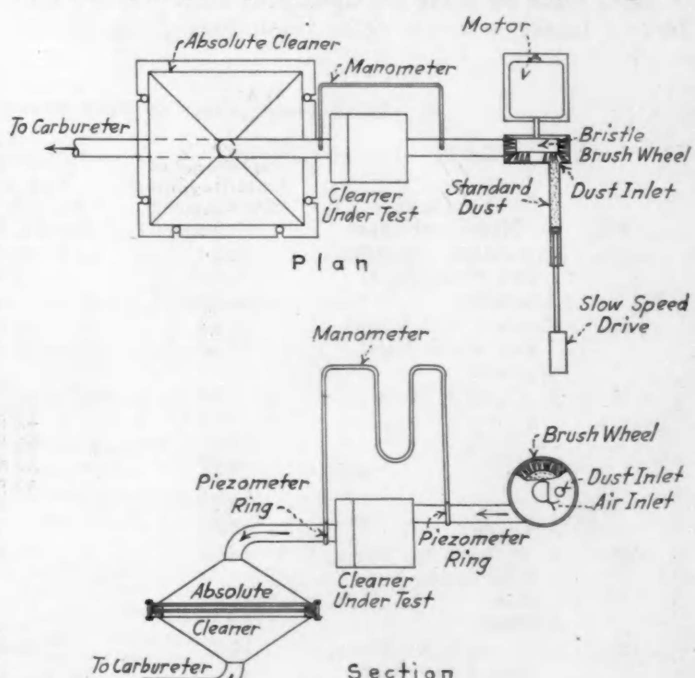


Fig. 4—Apparatus for Testing the Efficiency of Air-Cleaners

This Device Feeds the Dust Directly into the Inlet of the Air-Cleaner. A Bristle-Brush Wheel and Feeder of This Type Forces the Dust into the Wind-Tunnel Indicated in Fig. 1

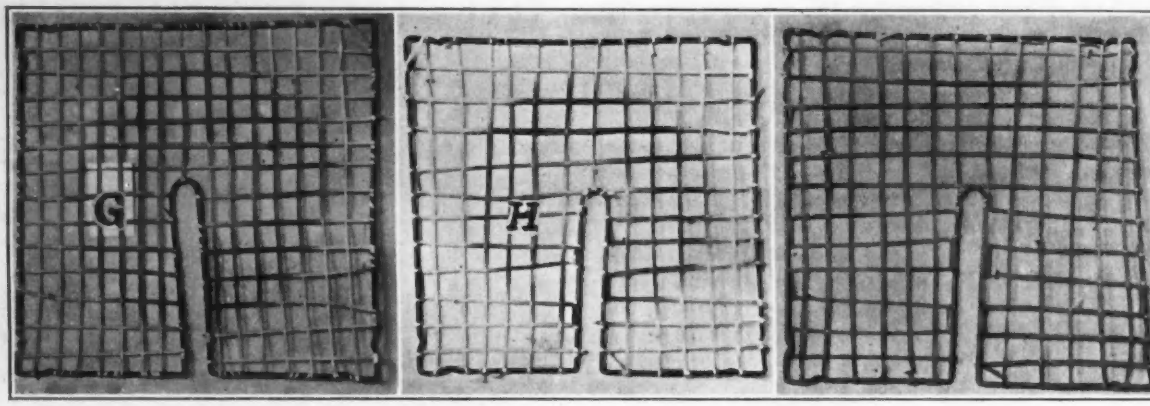


FIG. 5—DUST DISTRIBUTION IN THE WIND-TUNNEL
The View at the Left Indicates That, at Low Wind-Speed, the Concentration Was Greater in the Circle Made by Horizontal Projection of the Fan upon the Vertical Plane through the Standard Test-Position. The Center of the Air-Cleaner Inlet Is Located at *G*. As Shown in the Central View, at Medium Wind-Speed the Concentration Was Almost Identical with That at Low Wind-Speed. The Center of the Air-Cleaner Inlet Is Located at *H*. At High Wind-Speed, the View at the Right Shows That the Distribution Was More Nearly Uniform over the Entire Area

reduction gear pushes it into contact with the revolving bristle-brush, which brushes it in a fine cloud into the airstream entering the wind-tunnel. The time regularly used in sending in the dust-charge is 1 min., although other rates can be used. A 3-min. period was found to increase somewhat the percentage of dust that actually reached the air-cleaner, probably due to the finer state of division that would attend the slower feed, the brush-wheel running at constant speed. Exactly 10 min. after dust-feeding begins, the test is stopped by removing the connection between the air-cleaner under test and the absolute air-cleaner. At the close of a test, the air inside the wind-tunnel is not noticeably dusty, the dust that has not reached the air-cleaner having been thrown out against the periphery of the wind-tunnel by centrifugal action or deposited by gravity on the bottom surfaces.

FACTORS THAT AFFECT THE AMOUNT OF DUST REACHING THE AIR-CLEANER

Tests made by using the apparatus described are subject to larger probable error than those made by the older apparatus, in which the dust-sample is brushed directly into the airstream entering the air-cleaner undergoing test. This is due to a number of factors that influence the amount of dust that actually will reach the intake of the air-cleaner in its test position. (See Table 1.) Some of these factors, listed about in the order of their relative importance are:

(1) Quantity of dust fed into the wind-tunnel
(2) Rate at which air is drawn into the air-cleaner
(3) Total length of time this rate of airflow is maintained
(4) Position of the effective center of the air-cleaner intake in the wind-tunnel section and with reference to the fan
(5) Character and condition of the dust used
(6) Air-speed past the air-cleaner
(7) Rate at which dust-feeding takes place
(8) Method of dust-feeding, involving how fine is the brushing-out of the particles in the ingoing-dust cloud and at what point and at what inclination the dusty air enters the wind-tunnel

TABLE 1—QUANTITY OF DUST REACHING THE AIR-CLEANER UNDER TEST[5]

No.	Air-Cleaner Name and Type	Quantity of Dust Reaching Air-Cleaner, Grams	Airflow per Minute at 60 Deg. Fahr. and 14.7-Lb. Pressure Per Sq. In., Cu. Ft.	Room Temperature, Deg. Fahr.	Relative Humidity, Per Cent	Barometer, In. of Mercury
7	Donaldson, Old-Model	13.51	51.7	94	22	30.013
	Dry Centrifugal	13.48	51.5	96	22	30.010
	Average	13.50	...	...	...	......
23	Bennett, Old-Model	10.84	52.0	100	28	29.950
	Dry Centrifugal	12.48	51.5	102	22	29.916
	Average	11.66	...	...	...	......
65	A. C., with Stove	17.00	51.5	75	58	30.058
		15.53	51.5	78	53	30.064
		15.49	52.0	88	36	30.058
		15.93	51.5	90	36	30.058
		17.51	51.5	92	32	30.032
		16.71	51.5	92	37	30.000
	Average	16.36	...	...	...	......
65	A. C., with No Stove,	18.98	53.0	96	27	29.932
	Inlet toward the Fan	20.00	52.5	96	30	29.990
	Average	19.49	...	...	...	......
65	A. C., with No Stove,	14.05	52.7	95	25	29.752
	Inlet Away from the Fan	13.70	52.5	81	47	29.800
	Average	13.88	...	...	...	......
	Grand Average	14.98	...	...	...	......

[5] Obtained by using collecting-type dry centrifugal air-cleaners.

TABLE 2—SUMMARY OF TESTS OF AIR-CLEANERS OF THE RADIATOR-FAN TYPE

Air Cleaner No.	Make or Trade Name	Dust Separating Efficiency, Per Cent, Fan Speed: Low	Medium	High	Vacuum at 20.4 Hp. and 1200 R.P.M., In. of Water, Fan Speed: Low	Medium	High	Number of Tests Made
34	Wishon	....	27	14	...	6½	6½	3
47	Turbo-Automatic	....	27	..	...	1 5/16	...	1
48	Cyclone-Automatic	....	71	..	...	4¼	...	1
48A	Cyclone-Automatic, with Venturi Jet Ejector	51	57	65	3⅜	3 5/16	3⅞	5
56	I. & M. Perfection 4-In. Pressed-Steel	....	54	..	...	3	...	3
56A	I. & M. Perfection 5-In. Pressed-Steel	15½	42½	59	1	1 1/16	1⅜	5
56B	I. & M. Perfection 4-In. Cast-Aluminum	....	40	..	...	......	...	1
63	Heinss	....	32.5	..	Clean	1½	...	2
					End of Test	3	...	..
67	Improved 26 Motor Protector	....	94	..	Clean	1½	...	1
					End of Test	46¾	...	..

(9) Shape of the air-cleaner, especially as to the relative position of its intake
(10) How much of the sectional area of air-path in the wind-tunnel is occupied by the air-cleaner when in position for test
(11) Atmospheric humidity, temperature and pressure

Of the foregoing factors, Nos. 1, 3, 4, 5, 6, 7, and 8 were controlled as closely as possible in these tests. Causes of variation in factor No. 2 are given in the next paragraph. Factor No. 11 was partly under control in that it was sometimes possible to postpone a test pending the arrival of more favorable conditions.

Variations in Carbureter Air-Requirement

The rate at which air was drawn through the air-cleaners tested, uncorrected for the temperature of the water in the manometer used with the venturi air-meter, varied from 49½ to 54 cu. ft. per min. The variation was in spite of a constant brake-load of 20.4 hp. and a constant speed of 1200 r.p.m. maintained by manual control of brake and of throttle. Factors besides speed and load, affecting the carbureter air-requirement are the viscosity of the oil, the temperatures in various parts of the engine, the carbureter adjustment, the spark-advance, the condition of breaker-points, valves and piston-rings, and atmospheric conditions.

Effect of Wind-Speed

The tests were made mainly at normal fan-speed; that is, with the fan-shaft running at practically the same number of revolutions per minute as the engine was running. In general, the efficiencies were higher at higher fan-speeds, and lower at lower fan-speeds. The dust distribution over the section of the wind-tunnel at the standard test-position was mapped by using appropriate screens of felt strip lightly oiled. The left and the

TABLE 3—IDENTIFICATION OF AIR-CLEANERS OF RADIATOR-FAN TYPE

Air-Cleaner No.	Name	Manufacturer	Weight Clean, Lb.	Inside Diameter of Outlet, In.	Description	Size of Body Proper, In.: Height	Length	Width	Diameter
34	Wishon	Ralph Wishon, National Air Transport, St. Joseph, Mo.	1.3	1.70	Flat Cell, Louvers in Face	9	5.0	½	....
47	Turbo-Automatic	Charles J. Winslow, Vallejo, Cal.	3.4	1.88	Conchoidal Form	14	10.5	3	....
48	Cyclone-Automatic	Charles J. Winslow, Vallejo, Cal.	3.4	1.88	Frustum of Cone	9	....	..	6
48A	Cyclone-Automatic Ejecting by Venturi Jet	Charles J. Winslow, Vallejo, Cal.	2.3	2.05	Frustum of Cone	6	....	..	8½ 4⅕ 6
56	I. & M. Perfection 4-In. Pressed-Steel	Ireland & Matthews Co., Detroit	0.7	1.87	Cylindrical Shell over Cone	..	3⅞	..	4
56A	I. & M. Perfection 5-In. Pressed-Steel	Ireland & Matthews Co., Detroit	1.4	2.17	Cylindrical Shell over Cone	..	4⅝	..	5 1/16
56B	I. & M. Perfection 4-In. Cast-Aluminum	Ireland & Matthews Co., Detroit	1.0	1.70	Cylindrical Shell over Cone	..	3 13/16	..	3 13/16
63	Heinss	Heinss Air Cleaner Co., Fort Madison, Iowa	1.1	1.79	Conical; Three Vanes Revolved over Screen by Six-Bladed Windmill	..	....	..	5
67	Improved 26 Motor Protector	Orem Motor Protector Co., Baltimore	2.4	1.90	Filter Using Fan-Blast as Auxiliary	..	5	..	5¼

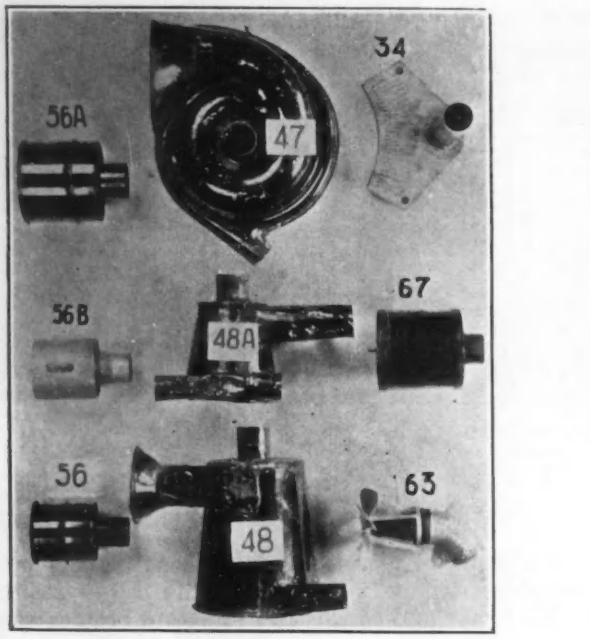


FIG. 6—RADIATOR-FAN-TYPE AIR-CLEANER

These Are Respectively No. 34, Wishon; No. 47, Turbo-Automatic; No. 48, Cyclone-Automatic; No. 48A, Cyclone-Automatic Equipped with a Venturi Ejector; No. 56, I. & M. Perfection, of 4-In. Pressed-Steel; No. 56A, I. & M. Perfection, of 5-In. Pressed Steel; No. 56B, I. & M. Perfection, of 4-In. Cast-Aluminum; No. 63, Heinss; and No. 67, Orem Improved 26 Motor Protector

central views in Fig. 5 show almost identical distribution at fan-speeds of 660 and 1220 r.p.m. These showed somewhat heavy concentration in the circular area directly behind the fan. At a fan-speed of 1660 r.p.m., as shown at the right in Fig. 5, the dust distribution is more nearly uniform over the entire section of the air-path. This effect, instead of an actual lowering of the efficiency, may have been responsible in part for the poorer showing of air-cleaner No. 34 in the high-speed test. Higher fan-speed increased the restriction of the air-cleaners under test, but so slightly as to be negligible in its effect on carbureter action.

Table 2 gives a summary of results, and the efficiencies there given can be compared directly with those published for the 1922 tests[6] and the 1924 tests[7]. The minimum vacuum-readings given in Table 2 are also directly comparable, but the maximum readings are for 15 grams of dust taken-in; whereas, those of the 1922 tables are for 150 grams and those of the 1924 tables are for 100 grams. Table 3 and Fig. 6 serve to identify the air-cleaners tested. All the air-cleaners listed use the inertia principle of dust separation. One, No. 67, uses, in addition to an inertia separation-device, a dry-cloth filter. Reference is made also to my paper on Selecting an Air-Cleaner, and to the discussion that followed it[8].

DESCRIPTION OF THE AIR-CLEANERS TESTED

Air-cleaner No. 34, Wishon, is a flat sheet-metal cell designed to be placed between the rear face of the radiator and the radiator fan, the fan-blade edges passing close by a set of narrow louvers in the side of the air-cleaner. The fan-blades are depended upon to throw away the dust particles from the air entering by the louvers. Data given for this air-cleaner were obtained with the air-cleaner in this designed position. All other air-cleaners were in the so-called standard test-position already specified.

The Turbo-Automatic air-cleaner, No. 47, is shaped somewhat like a snail-shell. A bell-shaped inlet receives the dusty air, which whirls around a horizontal axis. The dust is thrown out by centrifugal action and is caused to escape through a long narrow slit into an adjacent tube leading to the open air.

The shape of air-cleaner No. 48, Cyclone-Automatic, is that of the frustum of a cone. It has a funnel-shaped tangential inlet and a central vertical tubular clean-air outlet at the top, and a small tangential dust-outlet opening toward the rear at the bottom.

Air-cleaner No. 48A, Cyclone-Automatic, is similar to air-cleaner No. 48 but is smaller and has a straight instead of a flaring air-inlet; also, the dust-outlet has a venturi tube attached through which air from the fan-blast passes, tending by the lowering of the pressure in the section of restricted area to draw out and discharge the separated dust.

The No. 56 I. & M. Perfection air-cleaner of 4-in. pressed-steel, has a round-pointed conical shell covering the inlet end of the clean-air discharge-tube and a horizontal cylindrical shell open at both ends surrounding the cone. The air for the carbureter must whirl around the sharp edge of the cone, the inertia of the dust particles carrying them on in the fan-blast.

Air-cleaner No. 56A is the same as air-cleaner No. 56, except for its 5-in. size. Air-cleaner No. 56B is the same as air-cleaner No. 56, except that it is the older cast-aluminum model.

The No. 63 Heinss air-cleaner has a conical screened inlet over the curved surface of which three aluminum bars about $1/8 \times 3/8 \times 3\frac{1}{4}$ in. are revolved by the action of a six-bladed windmill 5 in. in diameter. The screen has a rectangular mesh, 50 x 60 per in.

Air-cleaner No. 67, Orem Improved 26 Motor Protector, has a cylindrical cloth filter 4 in. in diameter and $3\frac{1}{2}$ in. long surrounded by a cylindrical tube 5 in. in diameter and 5 in. long. A convex metal-plate covers the end of the filter facing the radiator fan. The fan-blast passes through the annular space between the filter and the tubular shell.

OBSERVATIONS

(1) This method and apparatus designed for testing air-cleaners of the radiator-fan type can be used for air-cleaners of practically any type. It has the advantage that the air-cleaner under test is conditioned almost exactly as it would be in regular service. The disadvantage is lower accuracy than can be secured by the older method

(2) Both methods involve laboratory tests of short duration which cannot adequately take into account the effects of conditions often arising in long-period road-service, such as vibration and the presence of fog and oily vapors

(3) It will be noted that air-cleaners of the radiator-fan type were found generally satisfactory as to restriction effect, but unsatisfactory as to efficiency

(4) Since air-cleaners using the radiator-fan blast as an auxiliary must necessarily be directly in the fan-blast, they are under the handicap of having to contend with dustier air than might be had at more favorably located places under the hood

[6] See University of California Agricultural Experiment Station Bulletin, No. 362.
[7] See THE JOURNAL, March, 1925, p. 367.
[8] See THE JOURNAL, March, 1927, p. 393.

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Development of the High-Speed Diesel Engine

By P. M. HELDT[1]

INDIANA SECTION PAPER *Illustrated with* PHOTOGRAPHS AND DRAWINGS

ABSTRACT

AN original definition of a four-stroke Diesel-engine is given by the author, who then presents a short history of high-speed Diesel-engine development which includes mention of the main features of the following engines: Junkers, Attendu, Sperry, Beardmore, Hindlmeier, Lang, Benz, M. A. N., Maybach, Peugeot, and others. The engineering problems relating to Diesel engines for automotive use are then discussed, with emphasis on the factors of atomization and distribution of the fuel in the air-charge, turbulence and airless fuel-injection, including types of igniter suitable for engines equipped with an antechamber.

As to the possibilities of the oil-burning engine in the automotive field, the author says that the two main advantages it offers are reduced fuel-cost and reduced fire-hazards and that its chances are greatest wherever these are important factors. He believes that this type of engine will not come into use on passenger-cars within a reasonably short time since fuel cost contributes only a small fraction to the operating cost of a passenger-car and its fire hazard is almost negligible. Reduction in fuel cost for motor rail-cars that are equipped with an oil-burning engine will have a beneficial effect on net earnings and, if the problem of a suitable transmission can be solved, this field seems clear for engines of that type and they may be developed further so as to become available for smaller vehicles. Such engines already seem suited for heavy motor-trucks in services where high speeds can be maintained over long periods.

Following the paper, a brief summary of the advantages and disadvantages of the Diesel engine for automotive purposes is made by an eminent consulting engineer.

ONE of the engineering developments of the next decade undoubtedly will be a wide application of the Diesel or oil-burning engine to transportation on land. Originally, the Diesel was built as an engine of medium size for stationary-engine purposes, in which size its production seemed to offer the minimum number of difficulties. The first motorship was launched in 1912 and the development of the Diesel as a marine engine has since made such rapid progress that at present more than one-half of all the world's shipping under construction is designed for motor-driven propulsion. The difficulties attending an increase in size of engine to a size suitable for propelling ocean-going vessels have to do mainly with the cooling of such parts as the pistons and valves.

The oil-burning engine has not yet made as much headway in land transportation, although much development work has been done. It was announced recently that a Diesel-electric locomotive for one of our railroad companies had been built by the Baldwin Locomotive Works, Philadelphia, in cooperation with the General Electric Co., Schenectady, N. Y. A number of press references to a Diesel-electric locomotive built in Germany according to the designs of a Russian engineer, for use in a district of Russia where water is very scarce, have also appeared. Much other work on internal-combustion-engine locomotives is under way in Europe. The difficult problem is that of power transmission to the driving

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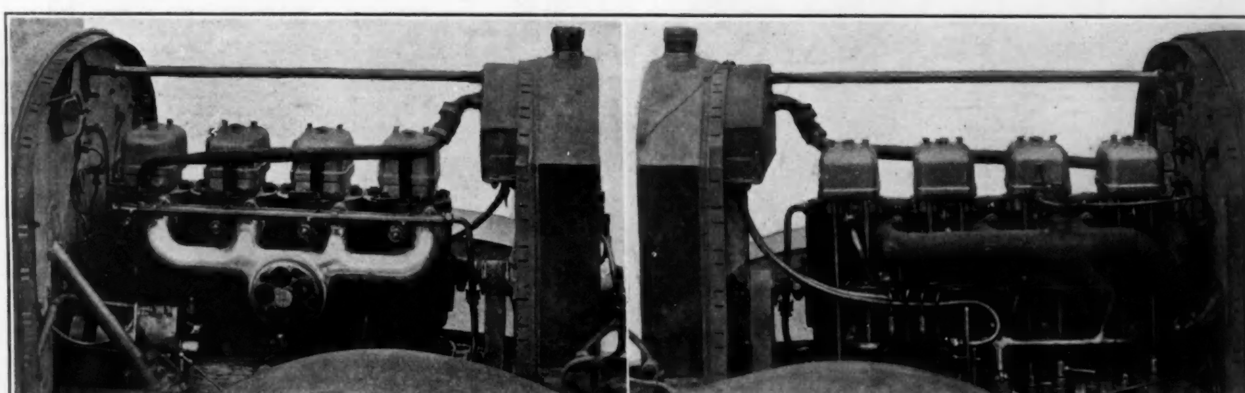

FIG. 1—BENZ AUTOMOTIVE DIESEL-ENGINE
The Engine Is of the Ignition-Chamber Type, in Which the Fuel Is Injected under Comparatively Low Pressure into a Small Chamber Separated from the Combustion-Chamber Proper. Combustion Starts First in the Ignition-Chamber Where, Owing to the Small Quantity of Air Present, only a Small Fraction of the Fuel Injected Can Burn. The Increase in Pressure in the Ignition-Chamber Due to the Combustion Therein Forces the Remainder of the Fuel through Spray Orifices in a Bushing Connecting the Ignition-Chamber with the Combustion-Chamber. The Advantages Are That a Much Lower Fuel-Injection Pressure Can Be Used, and That the Injection Orifice Can Be Made Larger

wheels. Electric transmission is satisfactory from the operating standpoint, but it is expensive in first cost, and the necessary equipment is very heavy. Experiments are being made with hydraulic and with direct mechanical transmissions.

Experimental Diesel engines have been built in practically all sizes, even including one for a motorcycle. If it were merely a question of reducing the displacement of the individual cylinders, the only difficulty likely to be met would be that due to metering accurately the extremely small quantities of liquid fuel required per charge. But for automotive work it generally is necessary to reduce the weight per horsepower materially. This necessitates operation at comparatively high speed.

For the benefit of those who may have only a hazy idea of what a Diesel engine is, I have prepared the following definition. A four-stroke Diesel-engine is similar to the conventional automobile engine except for these particulars: Instead of drawing in a combustible charge of air and gasoline vapor, it draws in air only. During the compression stroke, instead of compressing this air to one-quarter or one-fifth, it is compressed to one-twelfth or one-fifteenth of its original volume. At the end of the compression stroke, the fuel is injected through a nozzle, or jet, and on account of the high compression of 12 to 1 or 15 to 1 the air is heated to such a temperature that the fuel ignites spontaneously on being injected; hence, no ignition apparatus is required. On the other hand, while no carburetion is required, a fuel-pump and an injector-valve are needed for each cylinder.

As compared with carbureter-type engines, the Diesel holds out the two main advantages of a great reduction in the fuel cost and almost complete elimination of all fire hazards. It is for this latter reason that the air services of the leading industrial nations are greatly interested in seeing the oil-burning engine reduced in weight sufficiently to become practicable for aircraft propulsion. As regards fuel consumption, a Diesel engine, because of the much higher compression-ratio used and the consequent increase in thermal efficiency, should produce 1 hp-hr. on about 75 per cent of the fuel consumed by a carbureter-type engine. Diesel engines, moreover, operate on low-grade fuel that costs only one-fourth as much as gasoline, or less.

High-Speed Diesel-Engines

A brief review of what has been done so far in developing the Diesel or oil-burning engine for high-speed work is of interest. The first Diesel engine that properly can be classed as high-speed was built at St. Petersburg, Russia, in 1909, and was designed to be used in a yacht. It was an eight-cylinder V-type engine operating on the four-stroke cycle. Its cylinder dimensions were about 8 x 9 in. and it developed 200 hp. at 600 r.p.m., the weight being 4450 lb. or 22¼ lb. per hp. Fuel injection was by air.

During the War period much development work was done on Diesel engines for submarines, and some thought was given to the possibility of developing this type of engine for aircraft purposes. Hugo Junkers, in Germany, designed an oil-burning aircraft-engine which had two pistons within a single cylinder. Recently, Junkers completed an eight-cylinder engine of the double-piston type and flights of several hours' duration are reported to have been made with it. Since the time of the first report concerning the Junkers engine, interest in heavy-fuel aircraft-engines has been constantly on the increase in the air services. The Eastern Engineering Co., Montreal, Canada, built an engine of the two-stroke type for the American Navy in 1925. Details of this engine were given in a paper by A. C. Attendu, the designer[2].

[2] See THE JOURNAL, February, 1926, p. 214.

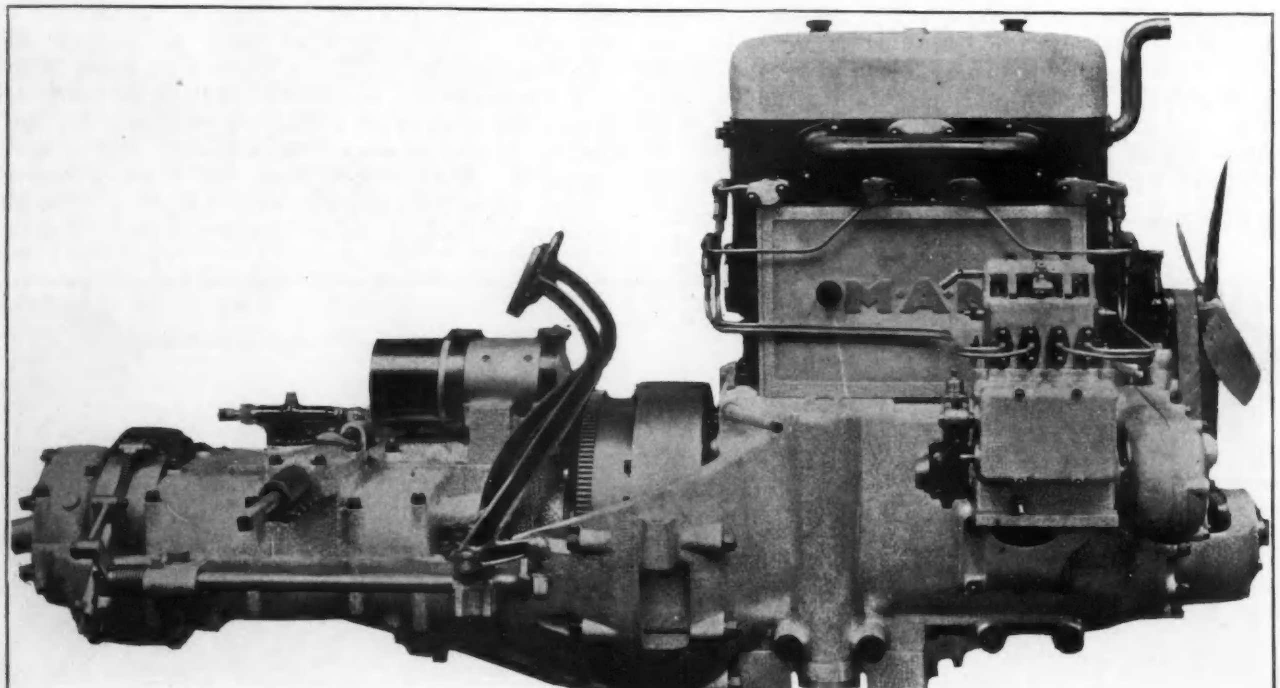

Fig. 2—The M.A.N. Motor-Truck Engine
This Four-Cylinder Engine Is Similar in External Appearance to a Carbureter-Type Engine. The Fuel-Pump Replaces the Magneto. The Fuel-Injection Nozzles, Two per Cylinder, Occupy the Positions of the Spark-Plugs. Fuel Is Injected by Mechanical Means Directly into the Combustion-Chamber. The Nozzles Are Open; That Is, They Contain No Valve. The Last Valve in the Fuel-Injection System Is the Discharge-Valve of the Fuel-Pump

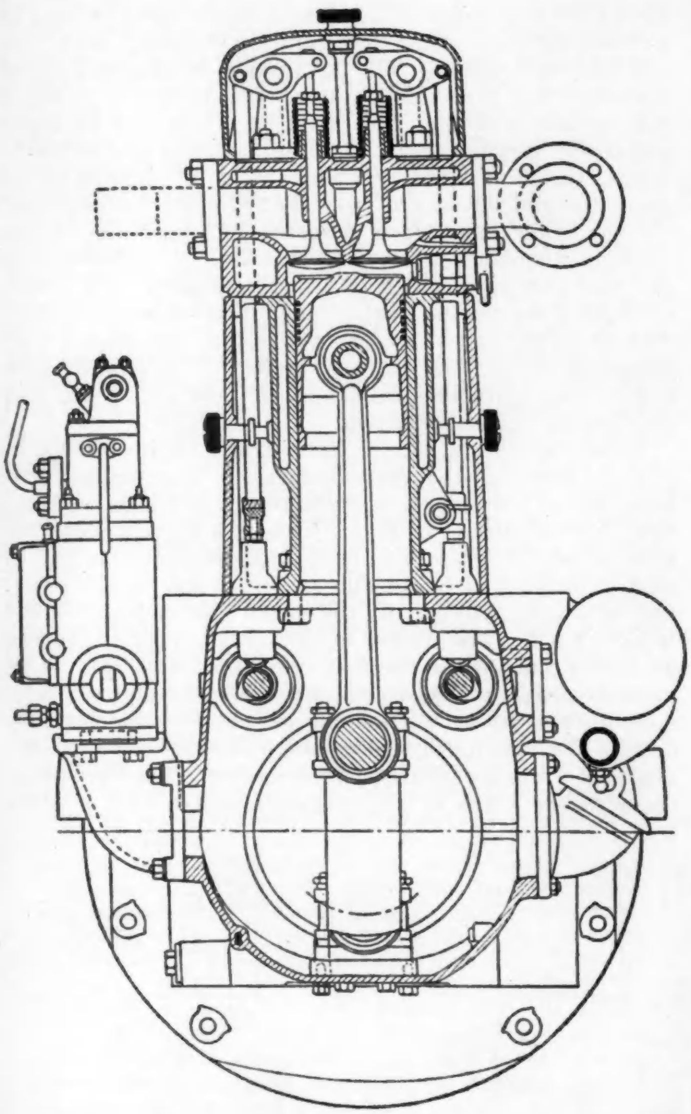

FIG. 3—SECTIONAL VIEW OF THE M.A.N. MOTOR-TRUCK ENGINE
The Weight Is 22 Lb. per Hp. for the 50-Hp. Rating at 1000 R.P.M. The Fuel Consumption Is Said To Be Most Favorable at 800 R.P.M. When, Under Full Load, It Is 0.44 Lb. per Hp-Hr.

I understand that this engine finally was developed to a stage which satisfied the Navy and that it was accepted.

At present, Elmer A. Sperry, of the Sperry Gyroscope Co., Brooklyn, N. Y., is developing an oil-burning four-stroke-cycle engine and is incorporating the features of supercharging and compounding. Mr. Sperry previously has built small oil-burning engines that work on the compound principle and exhibited an engine-generator set comprising such an engine at the New York automobile show about 5 years ago.

The development in England of the oil-burning engine for aircraft work has been taken up in a systematic way. A lengthy report on the prospects of making the heavy-oil engine available was made by a committee to the Air Ministry some time ago. In this it was pointed out that the effective weight of the powerplant for an airplane is the total weight of the engine plus the weight of the fuel. Any reduction in the weight of the fuel necessary for a given journey can be charged off against any increased weight of the engine itself. The longer the journey is, the more will high fuel-economy compensate for a heavier engine. The compression-ignition engine of 3 lb. per hp. can compare with a gasoline engine of 2 lb. per hp. The important factor that enters at this point is that the Diesel cycle, with its high pressures and high expansion-ratio, is able to deliver the same horsepower at a fuel consumption considerably lower.

A compression-ignition engine built in England by William Beardmore & Co. is said to have developed 1 hp-hr. on a fuel consumption of 0.365 lb. of fuel, which is far better than any results so far obtained from a carbureter-type engine. This engine is said to be similar in most respects to the Beardmore engine for motor rail-cars, of which some particulars will be given later, the chief differences being that an aluminum alloy replaces cast steel for the structural parts and that the engine is run at much higher speed.

In Italy, an oil-burning engine for aircraft has been built to the designs of Garuffa. It is a two-stroke-cycle engine, built in both V-type and radial-type models, and is said to have given satisfactory results in block tests. Nothing has so far been reported from France as to any development work on oil-burning aircraft-engines there, but this is no proof that no work has been done there, for there is a natural tendency to withhold information regarding development work of even partially a military character.

The problem of really small high-speed Diesel-engines seems to have been attacked first in Austria and in Germany. In 1922, a report was received in this Country that a small Diesel-engine suitable for automotive purposes had been developed by Joseph Hindlmeier of Vienna. The so-called Hindl engine generally was built in one-cylinder and in two-cylinder types for stationary-engine work, but a four-cylinder engine had been built for motor-truck use which, it was stated, operated at 1150 r.p.m. The company which developed the engine had its works at Moedling, near Vienna, and it was stated at that time that licenses for the manufacture of the engine had been issued to companies in Brunn, Austria; Cracow, Poland; Bucharest, Roumania; and Paris,

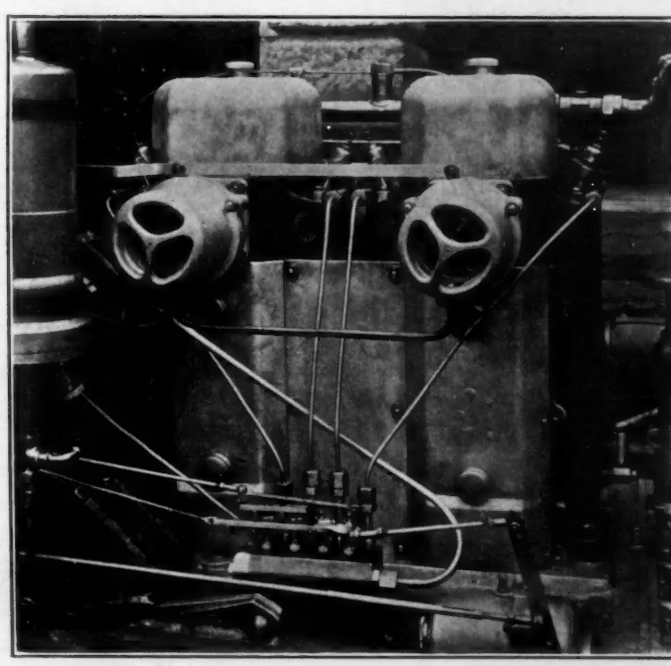

FIG. 4—M.A.N. DIESEL-ENGINE WITH ACRO-BOSCH EQUIPMENT
The Engine Is of the Usual Valve-In-Head Type, the Valves Being Operated from Two Camshafts in the Crankcase through Push-Rods Extending Up through Enclosed Spaces on Opposite Sides of the Cylinder-Block. The Two Air-Inlets, Which Are Part of the Acro-Bosch Equipment, Are Evident in the Foreground

France. A license was secured later by the Climax Engine Co., Clinton, Iowa.

Franz Lang, who, like Hindlmeier, was a former associate of Diesel, came to this Country in 1923 with a single-cylinder Diesel-engine of a design that was said to lend itself particularly to high-speed work and, therefore, to automotive applications. The American Crude Oil Motors Corporation was formed at the time to exploit Lang's patents here. The American venture seems to have come to naught. Lang was backed by Swiss capital and his patents were assigned to the Acro Co., of Knussnacht, Switzerland, which is now under control of the Robert Bosch Co., Stuttgart, Germany.

Probably the first German automotive Diesel-engine to reach a commercial stage was the Benz, shown in Fig. 1, which was first described in this Country in October, 1925, and was exhibited at the Berlin automobile show held at about that time. It was made in a two-cylinder form for farm tractors and in a four-cylinder form for motor-trucks. It was rumored that the motor-truck engine was later dropped, or at least that its development was not continued, although numerous tractor engines have been built. The engine is of the antechamber or ignition-chamber type, in which the fuel is injected under comparatively low pressure into a small chamber separated from the combustion-chamber proper. Combustion starts first in the ignition-chamber where, owing to the small quantity of air present, only a small fraction of the fuel injected can burn. The increase in pressure in the ignition-chamber due to the combustion therein forces the remainder of the fuel through spray orifices in a bushing connecting the ignition-chamber with the combustion-chamber. The advantages of this method of operation are that a much lower fuel-injection pressure can be used and that the injection orifice can be made materially larger. Both of these features are advantageous, the first from the standpoint of reliability of operation and the second from that of ease of production. On the other hand, it is asserted by opponents of the ignition-chamber system that it makes it impossible to get desirably high mean effective pressures. The four-cylinder Benz engine has cylinder dimensions of 4.93×7.09 in., develops 31 hp. at 800 r.p.m. and has a fuel consumption of 0.46 lb. per hp-hr. The two-cylinder engine has cylinder dimensions of 5.32×7.88 in. and develops 30 hp. at 800 r.p.m.

Details of the M. A. N. motor-truck engine shown in Fig. 2, built by the Maschinenfabrik Augsburg-Nürnberg, one of the pioneer manufacturers of Diesel engines, were first published in 1926. This is a four-cylinder engine of about $4\frac{1}{2} \times 5\frac{7}{8}$-in. cylinder-dimensions and is said to develop 32 hp. at 600 r.p.m., 42 hp. at 800 r.p.m. and 50 hp. at 1000 r.p.m., the output increasing further to 1200 r.p.m. The weight is 22 lb. per hp. for the rating at 1000 r.p.m., while the fuel consumption is said to be most favorable at 800 r.p.m., when, under full load, it is 0.44 lb. per hp-hr. This engine is of very clean-cut design and can hardly be distinguished in external appearance from a carbureter-type engine. The fuel pump occupies the place of the magneto and is only slightly

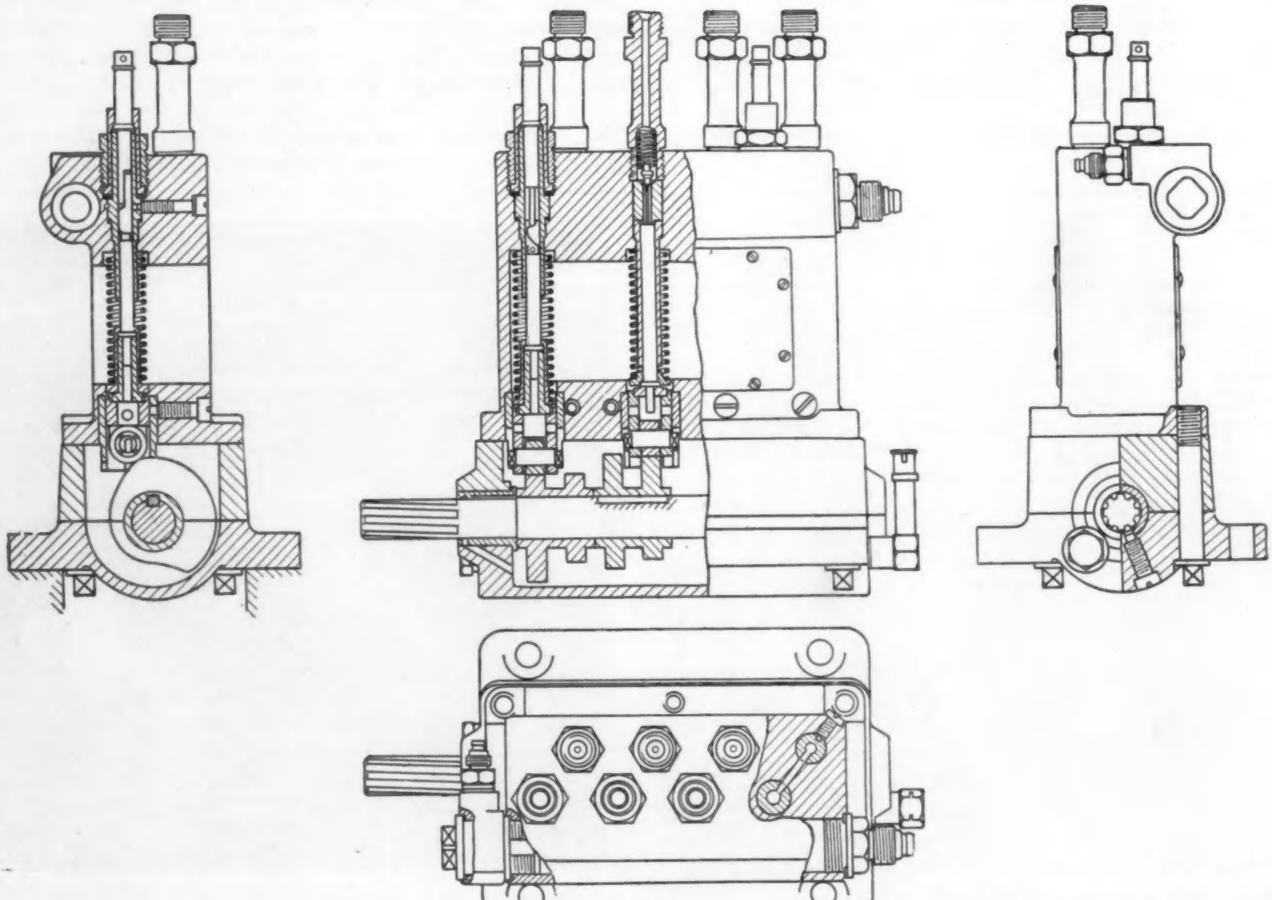

FIG. 5—ASSEMBLY VIEWS OF THE M.A.N. MOTOR-TRUCK ENGINE
The Fuel-Pump Is at the Side and Is Driven from the Front-End Gears through the Enclosed Centrifugal Governor. The Pump Comprises a Single Shaft Carrying Cams for Operating the Pump-Plungers and the Pump-Valves. The Valve Is of the Rotary Piston-Type

larger, while the injection nozzles, of which there are two per cylinder, occupy the places of the spark-plugs, of which also two are used occasionally on large engines. In this engine the fuel is injected by mechanical means directly into the combustion-chamber. The engine has the peculiarity that the nozzles are open; that is, they contain no valve. The last valve in the fuel-injection system is the discharge-valve of the fuel pump. Fig. 3 shows a sectional view of the M. A. N. engine.

Another well-known firm in Germany that has occupied itself with oil-burning engines in recent years is the Maybach Engine Co. of Friedrichshafen. Maybach was the engineering associate of Daimler in the development of the high-speed gasoline-engine for automobiles, and he is also known as the builder of all or practically all the engines used for propelling Zeppelin airships. The Maybach crude-oil engine, which is designed for use on motor rail-cars as well as for marine work, is a six-cylinder engine developing 120 to 130 hp. at 1300 r.p.m. It is one of the few automotive-type Diesel-engines using air injection for the fuel. Since most of the champions of the oil-burning engine consider air injection unsuitable for this class of work, it is of interest to quote the arguments of the Maybach company to justify the adoption of this system. In a pamphlet entitled, "Why not airless?" the company says:

> If it is desired to produce a really practical vehicle-type Diesel-engine it is necessary to deviate from previous design-practice and aim at the highest weight-efficiency and space-economy. In addition, the engine must be extremely flexible, the same as the modern automobile engine; that is, it must operate economically and satisfactorily under all loads and speeds. For vehicles it is, in addition, highly desirable to have a high starting-torque. To meet these requirements it was necessary to take special measures. It was especially clear that only perfect regulation of the injection air and of the injected fuel could give that degree of elasticity which is desired in a vehicle engine. To assure such accurate dosing by metering of the liquid fuel alone is perfectly hopeless. It is only necessary to consider what infinitesimal quantities of fuel are involved in such a high-speed multiple-cylinder vehicle-engine.
>
> To atomize such small quantities of fuel sufficiently, it is necessary to employ pressures of several hundred atmospheres and such small orifices or cross-sections that the enormous difficulties in their manufacture and in keeping them clear are directly obvious. This has been confirmed by experiment. So we were led naturally to air injection; only this permits the fine regulation which is characteristic of the Maybach high-speed crude-oil engine. There is no doubt that later on it will be found possible to build high-speed Diesel-engines also on the airless principle; but, in spite of all developments, it is still questionable whether the same degree of control will be attainable with these engines.
>
> As regards the compressor, it is possible to build it so that it will be thoroughly reliable. It is only necessary to see to it that it can be inspected easily. It is not necessary to fear undue cooling of the air in the cylinder by the injection air, provided the injection-valves are properly designed, as has been shown by long experience with such high-speed engines.
>
> After a thorough consideration of the reasons put forward by the proponents of airless injection, air injection was chosen for the high-speed crude-oil engine and thus an engine was produced which, on account of its compactness and its excellent control, is adapted to replace the gasoline engine thus far used.

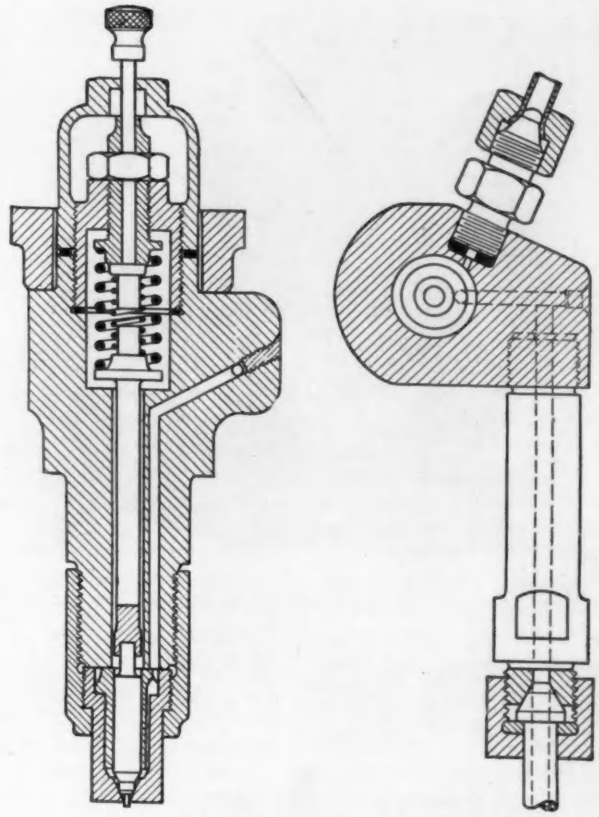

FIG. 6—M.A.N. ENGINE INJECTION-VALVE
This Valve or Atomizer Is of the Closed Type, the Conical Valve Being Held on Its Seat by a Strong Spring and Being Opened by the Pressure on the Fuel

Nearly 2 years ago the Robert Bosch Co., Stuttgart, Germany, which has been prominent in the manufacture of ignition and other electrical equipment, entered the Diesel-engine field by obtaining an exclusive license under the patents of Franz Lang, owned by the Acro Co. The Bosch Company realized that successful application of the oil-burning engine to automotive work might affect the market for magnetos and spark-plugs seriously and decided to tie-up with the new development at an early date. The Bosch Company points out that, in the manufacture of the fuel pumps and injection-valves for these small high-speed engines, the same class of precision work is required as in the manufacture of magnetos, and it feels that it is particularly fitted to undertake this class of work. The Company, therefore, plans to make only these parts and to license engine-builders under its patents which also cover other features besides those of the pump and the injector.

The Acro-Bosch equipment has been applied to a number of motor-trucks, including a four-cylinder M. A. N. truck, the engine of which is illustrated in Fig. 4. This engine was originally designed for operation on the Diesel cycle and has crankshafts, connecting-rods and bearings that are somewhat larger than the corresponding parts in a carbureter-type engine of the same cylinder-displacement; hence, it lends itself particularly well to conversion. The engine is of the usual valve-in-head type, the valves being operated from two camshafts in the crankcase through push-rods extending up through enclosed spaces on opposite sides of the cylinder-block. In the foreground of Fig. 4 are the two air-inlets, which are part of the Acro-Bosch equipment. In these inlets, behind the inner one of the three-armed spiders, is located a spiral heating-coil, which serves to assist in starting in cold weather by preheating the incoming air. These coils are heated by current from a battery. Starting is

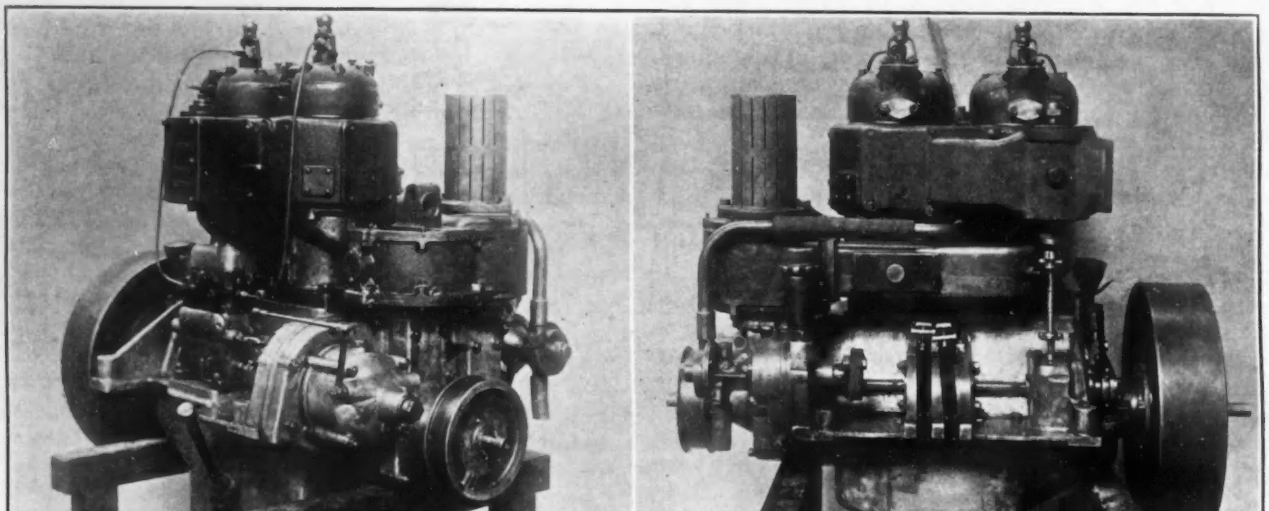

FIG. 7—PEUGEOT TWO-STROKE-CYCLE ENGINE
The Engine Has Two Cylinders and Its Two Pistons Work on Cranks Set 180 Deg. Apart. There Are Two Power-Strokes per Revolution

further facilitated by a choke-valve in each air-inlet which is about one-half closed for starting and also during long coasts of the vehicle.

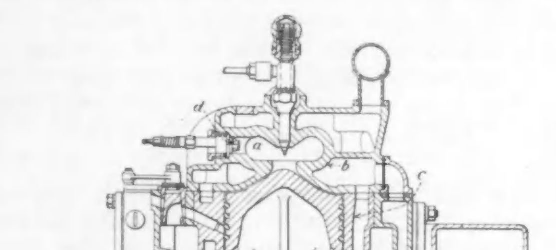

FIG. 8—CROSS-SECTION OF THE PEUGEOT HEAVY-OIL ENGINE
The Combustion-Chamber *a* in the Cylinder-Head *b* Is Separated from the Cylinder *c* and Is Shaped To Cause Maximum Turbulence. The Compression-Ratio Is Moderate and, for Starting, Use Is Made of an Electric-Wire Igniter, *d*, Which Screws into the Side of the Water-Cooled Combustion-Chamber *a*

The fuel pump is located at the side of the engine, as shown, and is driven from the front-end gears through the enclosed centrifugal governor. A number of assembly views are shown in Fig. 5. The pump comprises a single shaft carrying cams for operating both the pump-plungers and the pump-valves. This shaft is in the lower part of the housing and is connected to the governor-shaft through the timing-coupling, the splines on the pump-shaft being at a slight angle as shown, so that, by shifting the coupling member lengthwise, the moment at which injection begins can be advanced or retarded.

The valve is of the rotary piston-type. A reciprocating motion is given it by the cam in conjunction with a spring which returns it. It cuts-off communication between the source of fuel supply and the pump-barrel during a certain period of the delivery stroke of the pump-plunger, and fuel is then injected into the engine cylinder through the atomizer. To an extension of the valve a lever-arm is secured, so that the valve can be rocked around its axis, which results in increasing or decreasing the length of the period of injection relative to the time of an engine cycle. From the bar connecting the valve lever-arms, connection is made to the accelerator-pedal. When the engine is idled, two of the fuel-valves are shut entirely and only two of the cylinders are firing. This has been found to maintain the temperature better, and probably it also results in reduced fuel consumption during idling periods.

A sectional view of the injection-valve or atomizer is shown in Fig. 6. It is of the closed type, the conical valve being held on its seat by a strong spring and being opened by the pressure on the fuel. A comparatively low injection-pressure is used, about 900 lb. per sq. in., but efficient combustion and a high degree of elasticity are claimed to be assured by the special form of combustion-chamber used. The engine can be idled at 350 r.p.m. and can be run under load down to 400 r.p.m. The compression-pressure of the engine attains about 450 lb. per sq. in., while the maximum pressure during combustion is about 550 lb. per sq. in. High fuel-economy is claimed, approximately 0.46 lb. per hp-hr. under full load and 0.52 lb. per hp-hr. under one-half load. The fuel used is gas-oil, free from asphalt, of 0.88 specific gravity. The M. A. N. motor-truck fitted with this engine had

been driven more than 1300 miles before it was shipped to this Country.

German engineers also have built very small oil-burning engines for use on passenger-cars and even on motorcycles although, in the case of these light vehicles, the saving due to the use of a cheaper fuel cannot be great. German engineering papers have printed descriptions and illustrations of the Dorner light car, built by the Dorner Oil Engine Co., Inc., of Hanover. This car has a two-cylinder V-type air-cooled engine of $2\frac{3}{4}$-in. bore and 4-in. stroke which develops normally about 4.50 hp. at 1400 r.p.m., having a fuel consumption of 0.60 lb. per hp-hr. It can be forced to 6.00 hp. at 1400 r.p.m., but in that case the fuel consumption is increased to 0.66 lb. per hp-hr. The fuel used is gas-oil.

A single-cylinder engine of 3.15-in. bore and 3.54-in. stroke has been built into a motorcycle by Frey & Fischer. It is said to develop about 6 hp. and to have a fuel consumption of 0.55 lb. per hp-hr.

A two-stroke-cycle engine for motor-truck and tractor purposes has been developed from designs of Tartrais by the Peugeot Automobile Co., in France. When originally brought out, about 5 years ago, the Tartrais engine was of the so-called hot-bulb type, but recently it has been modified materially in design. Two views of the Peugeot engine are shown in Fig. 7. The engine has two cylinders and its two pistons work on cranks set 180 deg. apart; so, since the engine works on the two-stroke principle, there are two power-strokes per revolution. As shown in Fig. 8, the combustion-chamber *a* in the cylinder-head *b* is separated from the cylinder *c*. It is of peculiar shape, designed to cause maximum turbulence. The compression-ratio is moderate and, for starting, use is made of an electric-wire igniter, *d*, which screws into a boss in the side of the water-cooled combustion-chamber *a*. With this engine it is necessary to

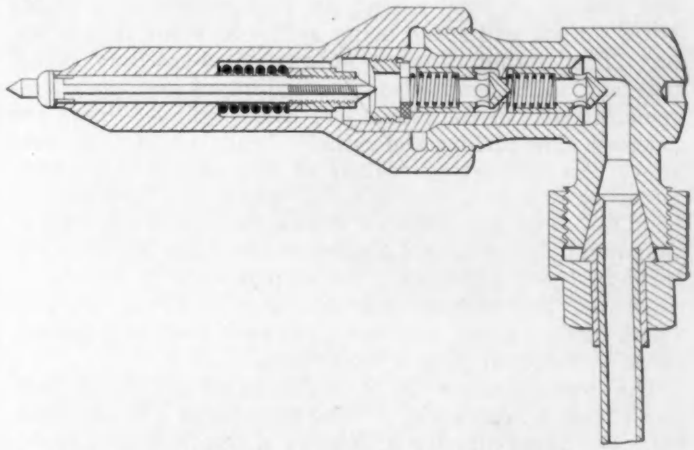

Fig. 10—Injector Used on the Peugeot Heavy-Oil Engine
The Consumption of Gas-Oil Is 0.45 Lb. per Hp-Hr.

use a fuel charge-pump, this being a piston-pump such as is shown in Fig. 9, which is mounted at the forward end of the engine in line with the cylinders. The engine has a 4.7-in. bore and a 5.9-in. stroke. It develops 41 hp. at 1300 r.p.m. and 53 hp. at 1450 r.p.m. The consumption of gas-oil is 0.45 lb. per hp-hr. under the most favorable conditions. The injector for the Peugeot heavy-oil engine is shown in Fig. 10. This engine weighs only 10 lb. per hp., according to the claim of the builder. An engine of this type was brought to this Country about 1 year ago by a delegation from the Peugeot Company. Attempts were made to interest American capital in the engine, but apparently without success.

Reference was made previously to the engine built by William Beardmore & Co. of England, for motor rail-cars. This is an eight-cylinder engine of $8\frac{1}{4}$-in. bore and 12-in. stroke which develops 172 hp. at 700 r.p.m.

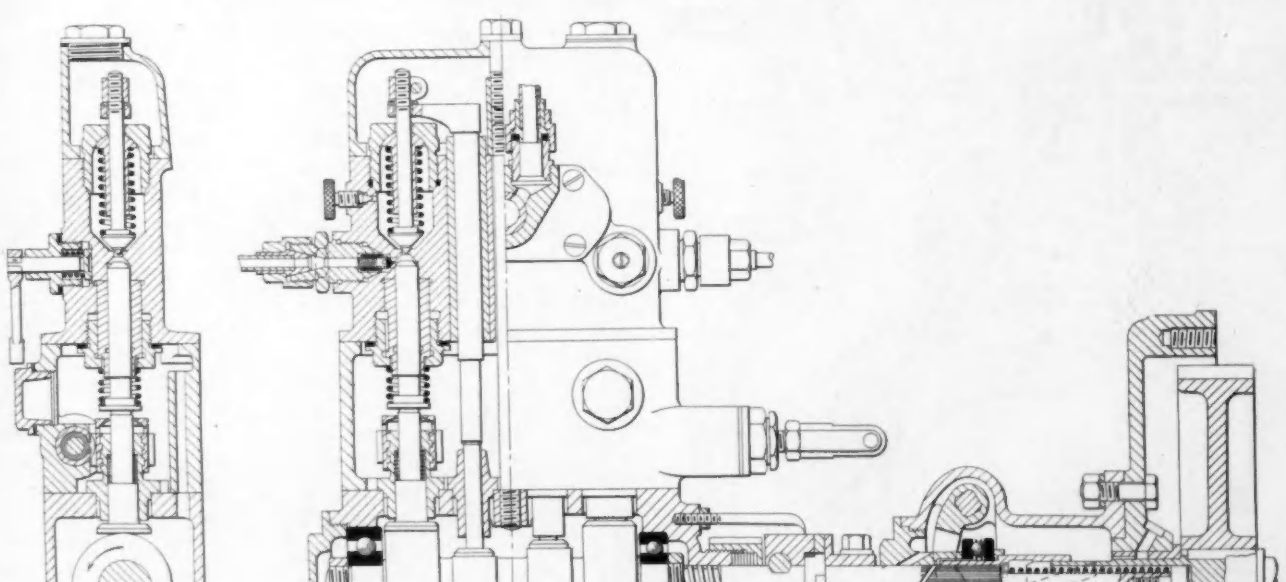

Fig. 9—Part of the Fuel-Injection System of the Peugeot Engine
This Engine Uses a Fuel-Charge Pump of the Piston Type Which Is Mounted at the Forward End of the Engine in Line with the Cylinders. Details of the Injector Are Shown in Fig. 10

and 224 hp. at 1000 r.p.m., the fuel consumption at the latter output and speed being as low as 0.365 lb. per hp-hr. The engine consists of two steel-castings bolted together, each comprising four cylinders and the corresponding part of the crankcase. Steel cylinder-liners are inserted. The pistons and cylinder-heads are of aluminum alloy. An interesting feature of this engine is its fuel-metering and injection system, which is illustrated in Fig. 11. The gear-pump *e* draws fuel from the supply tank and delivers it into a passage extending horizontally through the pump-block. An air-chamber, *f*, communicates with this passage near the outlet of the gear-pump *e* and, farther along, the passage is controlled by a piston-valve, *g*, referred to as a flash-valve.

The pump-plunger *h* is reciprocated at crankshaft speed from an eccentric, *i*. The flash-valve *g* is operated from the pump-plunger *h* through a double-armed lever, *j*, which rocks around an eccentrically mounted pivot, *k*. A delivery passage leads from the pump-chamber *l* to the distributor *m*, from which connection is made to injector-valves in two cylinders that fire at intervals of 360 deg. of crank motion, one of these injector-valves being indicated at *n*. The distributor *m* comprises a piston-valve, *o*, which is actuated through a lever, *p*, by an eccentric, *q*, on the camshaft of the engine. Through this distributor *m* the pump-chamber *l* is placed in communication alternately with the two injector-valves *n*, so that one pump suffices for two cylinders.

It will be noticed that the flash-valve *g*, midway of its length, has a portion of such diameter that it just fills the bore of the valve cylinder and that, adjacent to this, are two reduced portions. When the flash-valve *g* is at mid-stroke, its port is closed for a short time but, with the valve near either end of its stroke, the passage through it is open. When the pump-plunger *h* approaches the end of the suction stroke, the pump-barrel can fill completely with oil from the expansion-chamber *f*. During the first part of the return stroke the oil moved by the pump-plunger *h* will be returned to the expansion-chamber *f*, because the flash-valve *g* is then still open. At a certain point of the delivery stroke the flash-valve *g* is suddenly closed and, so long as it remains closed, the pump-plunger *h* forces oil through the distributor *m* which is open at that time, to the injector-valve *n*, which is opened by the pressure due to the pump action, and fuel is then injected into the engine-cylinder.

[3] See THE JOURNAL, February, 1926, p. 214.

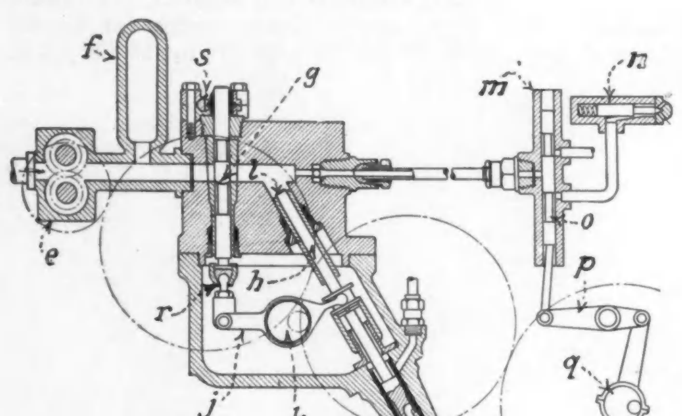

FIG. 11—BEARDMORE ENGINE FUEL-METERING AND INJECTION SYSTEM
The Gear-Pump *e* Draws Fuel from the Supply Tank and Delivers It into a Passage Extending Horizontally through the Pump-Block. An Air-Chamber, *f*, Communicates with This Passage Near the Outlet of the Gear-Pump *e* and, Farther Along, the Passage Is Controlled by a Piston-Valve, *g*, Referred to as a Flash-Valve. The Pump-Plunger *h* Is Reciprocated at Crankshaft Speed from an Eccentric, *i*. The Flash-Valve *g* Is Operated from the Pump-Plunger *h* through a Double-Armed Lever *j* Which Rocks around an Eccentrically Mounted Pivot, *k*. A Delivery Passage Leads from the Pump-Chamber *l* to the Distributor *m*, from Which Connection Is Made to Injector-Valves in Two Cylinders That Fire at Intervals of 360 Deg. of Crank Motion, One of These Injector-Valves Being Indicated at *n*. The Distributor *m* Comprises a Piston-Valve, *o*, Which Is Actuated through a Lever, *p*, by an Eccentric, *q*, on the Camshaft of the Engine. Through the Distributor *m* the Pump-Chamber *l* Is Placed in Communication Alternately with the Two Injector-Valves *n*, So That One Pump Suffices for Two Cylinders

The central enlargement of the flash-valve *g*, which cuts off the return flow of the fuel during the delivery stroke of the pump-plunger *h* has an inclined edge, and the valve is arranged so that it can be rotated around its axis. It has a ball-and-socket connection, *r*, to the operating lever *j* and, at the top, it carries a spur-pinion with which meshes a rack, *s*. By turning the flash-valve *g* around its axis by means of the rack *s*, the duration of the period of injection relative to the time of a cycle can thus be varied. It is claimed for this pump that, since the flash-valve *g* opens rapidly while the pump-plunger *h* is still on its delivery stroke, a sort of reflex action is set up in the fuel passage which results in a sharp cut-off.

DEVELOPMENT IN AMERICA

Coming now to work done on this continent, that of A. C. Attendu[3] for the United States Navy already has been mentioned. Development work on oil-burning aircraft-engines has been done also by Elmer A. Sperry, of the Sperry Gyroscope Co., Brooklyn, N. Y. I understand that Mr. Sperry has built several engines designed for aircraft use, all of which work is on the supercharging compound principle. A diagram of the engine is shown in Fig. 12. A supercharging cylinder or pump, *t*, precompresses air to a pressure of from 3 to 4 atmospheres (44.0 to 58.8 lb. per sq. in.). Air is delivered into the two high-pressure combustion-cylinders *u u*, alternately by the supercharging pump *t*, the engine working on the four-stroke cycle. When the pistons *v v* in the cylinders *u u* are down, the cylinders are thus filled with air having a pressure of from 3 to 4 atmospheres (44.0 to 58.8 lb. per sq. in.); but the compression-chambers are dimensioned so that, at the end of the upward stroke, the compression is no greater than that in the ordinary Diesel-engine. At the end of the power-stroke the pressure in the high-pressure cylinders *u u* is still about 150 lb. per sq. in., and the gases are then transferred to the low-pressure cylinder *w*, which is an expansion and cushioning cylinder located between the two high-pressure cylinders *u u*, in which they expand down to a pressure of about 15 lb. per sq. in. as indicated on the gage. Difficulty might be expected from the transfer-valves *x x* and *y y* which are subjected to high temperature of the partly expanded gases of combustion; but Mr. Sperry states that, on account of the comparatively slow speed of the gases past these valves, the valves stand up very well. The air-inlet is shown at *z* and the cushion-valve to the atmosphere at a_1. The form of the indicator cards from the combustion-cylinders *u u*, the low-pressure or expansion cylinder *w* and the pump *t* is shown.

In the field for the heavier types, high-speed Diesel-engines are being built in this Country by the Foos Gas Engine Co., Springfield, Ohio, and by the Cummins Engine Co., Columbus, Ind. Another Indiana company is

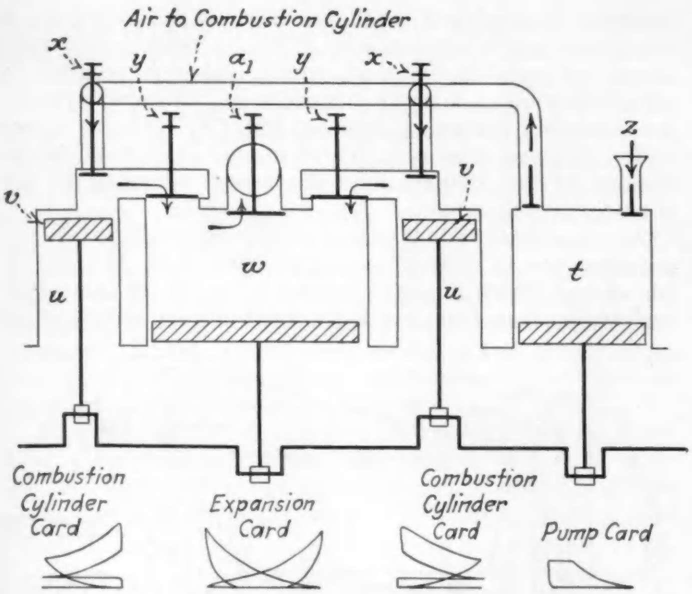

Fig. 12—Diagram of the Sperry Oil-Burning Aircraft-Engine
A Supercharging Cylinder or Pump, t, Precompresses Air to a Pressure of from 3 to 4 Atmospheres, (44.0 to 58.8 Lb. per Sq. In.) Air Is Delivered into the Two High-Pressure Combustion-Cylinders u u Alternately, by the Supercharging Pump t, the Engine Working on the Four-Stroke Cycle. When the Pistons v v in the Cylinders u u Are Down, the Cylinders Are Thus Filled with Air. At the End of the Power-Stroke the Gases Are Then Transferred to the Low-Pressure Cylinder w, in Which They Expand. The Transfer-Valves Are Shown at xx and yy. The Air-Inlet is at z and the Cushion-Valve to the Atmosphere at a_1. The Form of the Indicator Cards from the Combustion-Cylinders uu, the Low-Pressure Cylinder w and the Pump t Is Shown

engaged in the development of oil-burning engines for automotive purposes, this being the Super-Diesel Tractor Corporation, La Porte, Ind. I understand that this company has a special method of injecting fuel into the combustion-chamber, but I have been unable to learn any details concerning it.

The Maedler Engine Corporation, Cleveland, has been developing an engine in which it is sought to circumvent the difficulties connected with the metering of the exceedingly small volumes of liquid fuel by providing an auxiliary cylinder into which the gases of combustion and fuel are drawn during the down-stroke of the piston, the same as during the inlet stroke of a carbureter-type engine. This mixture is compressed during the following up-stroke to a pressure of about 600 lb. per sq. in., the mixture being non-explosive because of the absence of oxygen. At the end of the up-stroke, this highly compressed gaseous mixture is injected into the combustion-chamber of the working cylinder, where the fuel is burned on coming into contact with the air. Owing to the considerable time available and to the heat of compression the fuel is, no doubt, completely vaporized when it enters the combustion-chamber, in the design of which provisions are made to secure a high degree of turbulence, hence, the combustion should be good. This engine works on the two-stroke cycle and is provided with an integral charge-pump.

The Bendix Corporation, Chicago, Ill., has been developing the Gernandt engine in which fuel is injected into the combustion-chamber by super-compressing a portion of the products of combustion which are trapped at the time the pressure in the cylinder is at its maximum. During the suction-stroke fuel is deposited in a small chamber between the combustion-chamber and the super-compression cylinder, being metered and admitted through a mechanically timed valve. During the compression-stroke, the fuel heats up and the pressure in the fuel-chamber rises. At the end of the compression stroke the trapped products of combustion are super-compressed and, on passing through the fuel-chamber, they pick up fuel and carry it into the combustion-chamber.

The Climax Engine Co., Clinton, Iowa, which holds licenses under the Hindlmeier patents, has been doing development work on a six-cylinder 300-hp. engine, but details are lacking. The Buda Co., Harvey, Ill., has secured the rights under the M. A. N. patents for engines up to a certain size of cylinder and is developing its designs.

There have been reports of American licenses being granted for the manufacture of the Benz, the Beardmore and the M. A. N. engines in sizes of more than 50 hp. per cylinder. In connection with the Benz engine, no name was mentioned. The reported licensees under the Beardmore and the M. A. N. patents are two companies well known in the electrical field but, as I have been unable to confirm these reports, I do not feel warranted in mentioning them. I also have been told that a radial engine for motor rail-car use is under development by one of the companies referred to, the object being to eliminate the torsional vibration which always is troublesome in the multiple-cylinder so-called in-line engines and which is especially pronounced in Diesel engines on account of the high peak-pressures. Other companies in various parts of the Country undoubtedly are engaged in this line of work, but no news of their activities has come to me.

Engineering Problems of Diesel Engines

Atomization and distribution of the fuel in the air-charge can be promoted by high injection-pressures, fine

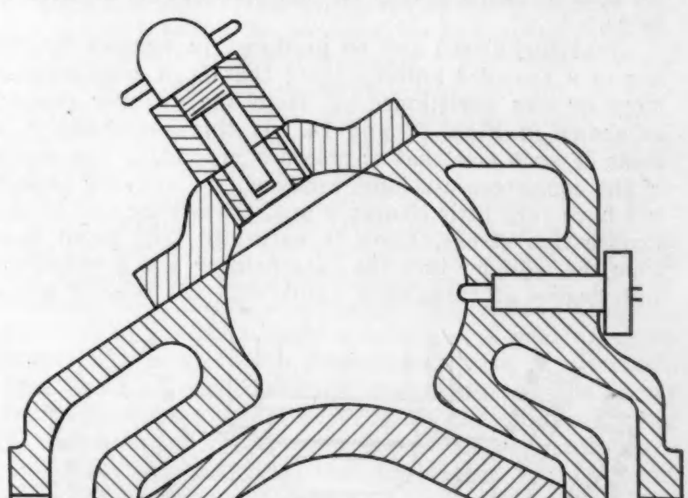

Fig. 13—Type of Antechamber for Increasing Turbulence
The Antechamber Is a Compartment Partly Partitioned Off from the Cylinder Proper. If this Antechamber Is Made of Such Size That It Provides Practically the Whole of the Compression-Volume Required, the Cylinder Proper Will Have Very Little Clearance and, Toward the End of the Compression Strokes, There Is a Very Rapid Flow from the Cylinder into the Antechamber and a Resulting High Degree of Turbulence. But with the Type of Antechamber Shown, the Purpose Is Not So Much the Creation of Turbulence As It Is the Retention of Heat from One Cycle to the Next, Which Makes Is Possible To Effect Ignition at a Lower Compression

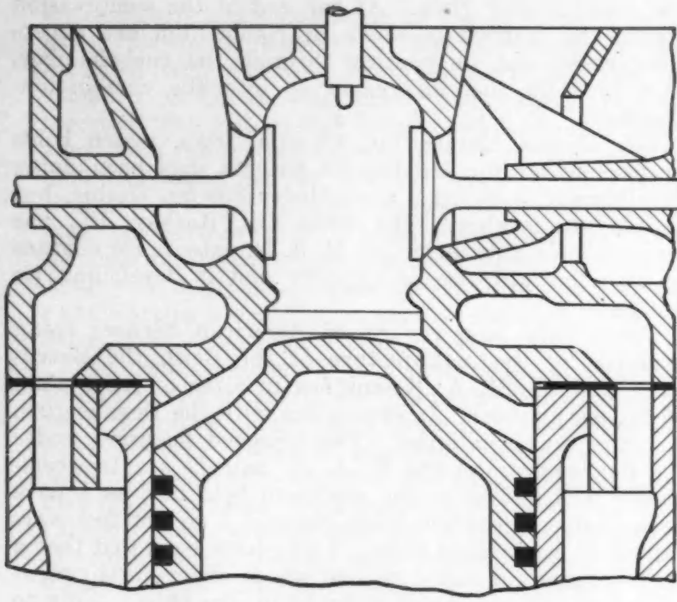

FIG. 14—ANOTHER TYPE OF ANTECHAMBER DESIGN
The Design Includes a So-Called Displacer-Piston, in Which a Somewhat Reduced Extension of the Piston Enters the Passage Leading to the Compression-Chamber

injector-nozzle jets and devices which tend to produce great turbulence of the air-charge. The subject of turbulence has been much discussed in connection with carbureter-type engines in recent years, but it is of even more importance in high-speed Diesel-engines. Fine atomization improves the combustion but, unfortunately, if the fuel is very finely sprayed, the penetration of the jet is decreased and it is on this account that turbulence helps.

Great turbulence can be produced in engines by the use of a so-called antechamber; that is, a compartment more or less partitioned off from the cylinder proper, as shown in Figs. 13 and 14. If this antechamber is made of such size that it provides practically the whole of the compression-volume required, the cylinder proper will have very little clearance and, toward the end of the compression stroke, there is naturally very rapid flow from the cylinder into the antechamber and a resulting high degree of turbulence. But with the type of antechamber shown in Fig. 13 the purpose is not so much the creation of turbulence as it is the retention of heat from one cycle to the next, which makes it possible to effect ignition at a lower compression. Another type of antechamber design, shown in Fig. 14, includes a so-called displacer-piston, in which a somewhat reduced extension of the piston enters the passage leading to the compression-chamber.

FIG. 15—TYPICAL GERMAN ANTECHAMBER-DESIGN
A Small Chamber in the Cylinder-Head Is Separated from the Combustion-Chamber Proper by a Throat in Which Is Inserted a Bushing That Is Closed at the End toward the Cylinder Except for a Number of Fine Orifices, $b_1 b_1$, Through Which the Fuel Is Sprayed

Another feature that can be combined readily with the antechamber is that of a surface swept by the air of the charge which is not in contact with the cooling-water and which, therefore, reaches a much higher temperature

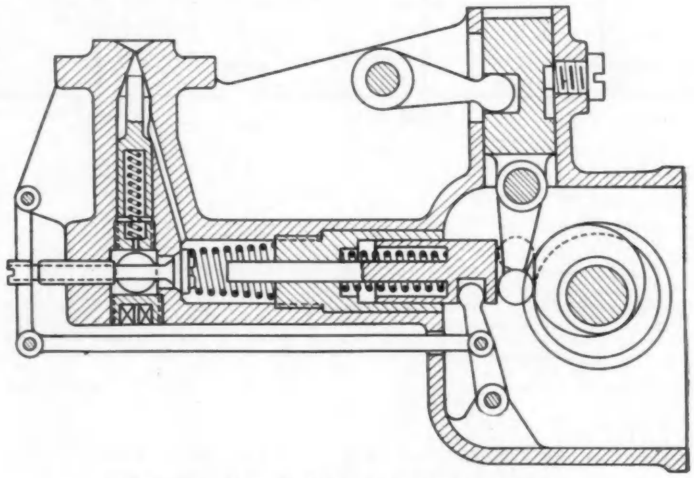

FIG. 16—COMBINED PUMP AND INJECTION-NOZZLE
The Stroke of the Pump-Plunger Is Varied To Control the Fuel Supply and Hence Controls the Engine-Torque

than that of the water-cooled walls of the cylinder. This, of course, improves the ignition. High-speed Diesel-engines of the antechamber type have been built by Benz and several other German builders. A typical antechamber design is shown in Fig. 15. A small chamber in the cylinder-head is separated from the combustion-chamber proper by a throat in which is inserted a bushing that is closed at the end toward the cylinder except for a number of fine orifices, b_1 b_1, through which the fuel is sprayed.

The pumps generally used for airless fuel-injection are ordinary piston-pumps or plunger-pumps. The full charge is wanted under full load only and there are, generally speaking, three methods of varying the amount of fuel injected into the engine-cylinder per cycle. The first of these consists in varying the stroke of the pump-plunger. For instance, if the pump-plunger is moved inward by a cam and returned by a spring, by placing a wedge which can be withdrawn more or less between the cam and the plunger, the effective stroke can be varied at will; or a roller mounted at the end of a link can be placed between the cam and the plunger. If the axis of the roller is directly in line with the axis of the cam in the direction of the plunger axis, the stroke will be maximum; but if the roller is withdrawn to one side the stroke will be reduced.

The combined pump and injection-nozzle of Dr. Frey is shown in Fig. 16. The stroke of the pump-plunger is varied to control the fuel supply and hence controls the engine-torque. Combining the pump with the injector-valve is an interesting feature that is most easily applied in the case of single-cylinder engines. One of the troubles with Diesel engines having solid injection is due to "after-dripping." Under the enormous injection-pressures sometimes used, up to 7500 lb. per sq. in., the fuel-pipes expand elastically and the fuel within

them compresses, since fuel oil is more compressible than water. Then, at the completion of the stroke of the plunger, when the pressure on the oil in the lines is relieved, the fuel-pipes contract again and the fuel within them expands, which tends to cause additional fuel to enter the engine after the regular injection-period has been completed. With the piping eliminated, this trouble disappears. Such trouble has been experienced from after-dripping that it has been proposed to provide in the pump a small extra plunger which moves slightly outward when injection ceases, so as to relieve the pressure on the oil in the line. It seems to be considered a better plan, however, to control the fuel-flow by valves and to make the pump of the constant-displacement type. Various types of bypass-valve have been used.

A simple type of pump with a bypass-valve, the Koerting, is shown diagrammatically in Fig. 17. A differential or double-diameter plunger, c_1 c_1, made in sections, is reciprocated by a cam, d_1, and a coiled spring, e_1. The

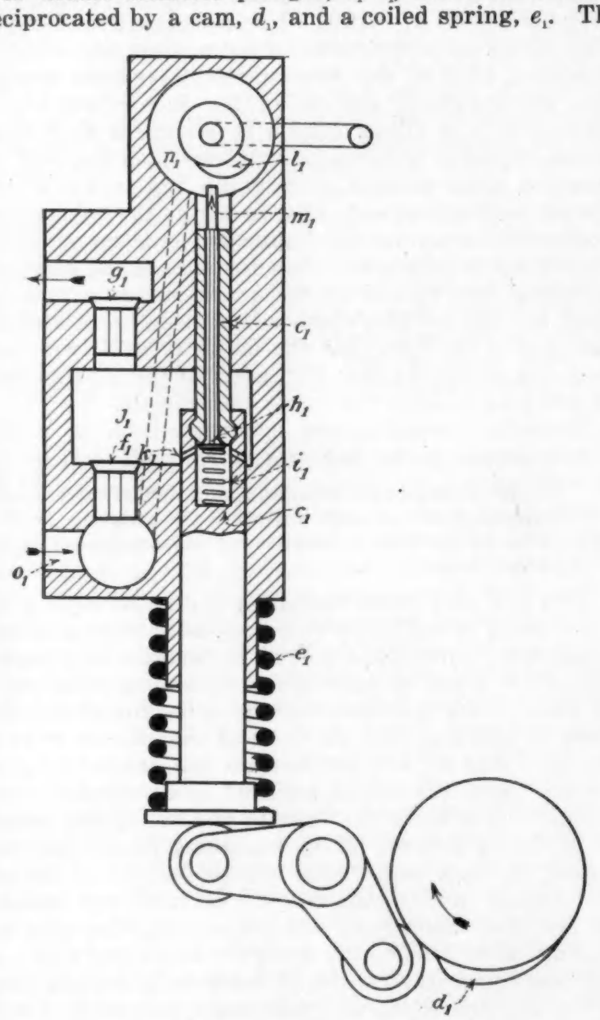

FIG. 17—FUEL-PUMP EQUIPPED WITH A BYPASS-VALVE

A Double-Diameter Plunger, c_1c_1, Made in Sections, Is Reciprocated by a Cam, d_1, and a Coiled Spring, e_1. The Suction-Valve f_1 and the Delivery-Valve g_1 Are Located in the Pump-Body. The Upper Part of the Double-Diameter Plunger c_1c_1 Is Drilled Out and Contains a Bypass-Valve, h_1, Which Is Held to Its Seat by a Light Coil-Spring, i_1, and the Pressure of the Oil, Which Oil Enters a Chamber, j_1, through Holes k_1k_1 in the Wall Thereof. The Cam l_1 Has a Spiral Cam-Surface Against Which the Stem m_1 of the Bypass-Valve h_1 Abuts When the Pump-Plunger c_1c_1 Is Lifted by the Pump-Cam d_1. When This Occurs, the Bypass-Valve h_1 Opens and Any Further Oil Moved by the Pump-Plunger c_1c_1 Passes through the Bypass-Valve h_1 into the Chamber n_1 in Which the Bypass Control-Cam l_1 Is Located, Whence It Returns to the Inlet-Passage o_1 through the Passage Indicated in Dotted Lines. By Rocking the Control-Cam l_1 around Its Axis, the Quantity of Oil Injected per Stroke of the Pump Can Be Varied

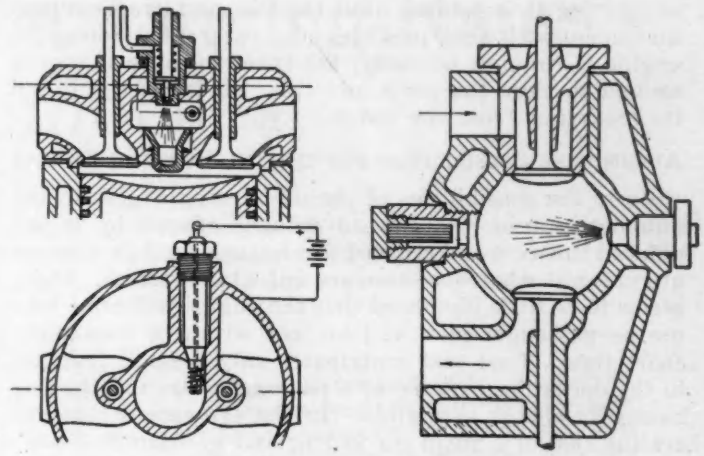

FIG. 18—ELECTRIC IGNITERS FOR OIL-BURNING ENGINES HAVING ANTECHAMBERS

In the Hot-Coil Type Shown at the Left the Coil Is Heated to Redness by Current from a Storage-Battery, the Current Being Turned Off As Soon As the Engine Is Running Steadily. The Cartridge-Type Igniter Is Shown at the Right

usual suction-valve f_1 and delivery-valve g_1 are located in the pump-body. The upper part of the double-diameter plunger c_1 c_1 is drilled out and contains a bypass-valve, h_1, which is held to its seat by a light coiled-spring, i_1, and the pressure of the oil, which oil enters a chamber, j_1, in the lower part of the pump-plunger through a number of holes, k_1 k_1, in the wall thereof. In the upper portion of the pump-body is located a cam, l_1, having a spiral cam-surface against which the stem m_1 of the bypass-valve h_1 abuts when the pump-plunger c_1 c_1 is lifted by the pump-cam d_1. When this occurs, the bypass-valve h_1 opens and any further oil moved by the pump-plunger c_1 c_1 passes through the bypass-valve h_1 into the chamber n_1 in which the bypass control-cam l_1 is located, whence it returns to the inlet-passage o_1 through the passage indicated in dotted lines. By rocking the control-cam l_1 around its axis, the quantity of oil injected per stroke of the pump can be varied at will.

With the antechamber system it is necessary to provide an auxiliary ignition-device because, when the engine is cold, the hot air flowing from the cylinder into the antechamber is cooled quickly by the walls of this chamber to a temperature below the ignition temperature. The igniter usually consists of a wad of paper which is saturated with potassium nitrate, a salt which ignites at a very moderate temperature. The paper burns slowly and continues to ignite the mixture during a succession of cycles until the engine has reached a sufficient temperature so that the charge will ignite by the heat of compression alone. It seems to be a good plan to place an igniter of this type directly opposite the injection nozzle, so that the fuel is certain to reach it.

The other type of igniter used is shown in Fig. 18 and consists of an electric coil which is heated to redness by current from a storage-battery. The current is turned off as soon as the engine is running steadily. Some difficulty seems to have been experienced from injury to the igniters due to their continual exposure to the heat of combustion. The coil is made of nickel-chromium wire and, in one design, it is mounted on a plug which screws into a boss in the wall of the ignition-chamber, which is completely surrounded by water. In another design the wire coil is placed inside a tubular member having an opening on one side, the tubular member being surrounded by a sleeve having a corresponding port. When the coil is to be used for starting, the tubular member

supporting it is rotated until the two ports register and air laden with fuel particles can enter; but, once the engine is running normally, the inner member is swung around to close the ports and this protects the coil and its mounting from the flame.

Automotive Possibilities for the Oil-Burning Engine

As to the possibilities of the oil-burning engine in the automotive field, the two advantages offered by it are reduced fuel-cost and reduced fire-hazards, and its chances are greatest wherever these are important factors. There seems to be little likelihood that the engine will come into use on passenger-cars, at least not within a reasonably short time. Fuel cost contributes only a small fraction to the operating expense of a passenger-car, and the fire hazard is almost negligible. In the estimate of the operating cost of a small car in England by Alan R. Fenn[4], the annual fuel-cost is given as $112.50 or 15 per cent of the total annual expenses of $750. Therefore, if a motorist could reduce his fuel expense say $75 by using a Diesel engine, he would reduce his total expense only 10 per cent and I believe that the average motorist would not be willing to endure the reduced flexibility and other inconveniences of the oil-burning engine for the sake of this slight gain in economy.

On the other hand, a motor rail-car engine of from 250 to 500 hp. may burn as much as $50 worth of fuel per day if operated on gasoline, and if two-thirds or more of this can be saved by the use of a Diesel engine it will have a great effect on the net earnings. In fact, it might convert a service that is unprofitable with gasoline into a highly profitable one. The problem of the large motor rail-car now seems to be that of a suitable transmission, and if this can be solved the oil-burning engine seems to have a clear field there. From the motor rail-car the engine no doubt will make its way downward into the field of smaller vehicles. It seems to be an excellent engine for heavy motor-trucks in services where high speeds can be maintained over long periods, as in intercity haulage. But the less the power required is and the more frequent the stops are, the smaller will be its advantages and the more serious its handicaps. In the industrial power-field, the engine already has gained a footing in this Country.

THE DISCUSSION

William G. Wall[5]:—To sum up some of the points brought out on how Diesel engines can be applied to automotive service, considerable experiment and research work is being done along this line which promises well for the future but, at present, the advantages and disadvantages of the Diesel engine as applied to motor-vehicles are as follows:

Advantages

(1) High thermal efficiency, 30 to possibly 35 per cent
(2) Very good economy at part loads
(3) Low cost of fuel, being about one-third to one-half the cost of gasoline
(4) Possible use of almost any liquid hydrocarbon fuel
(5) Fairly easy starting
(6) Complete fuel-combustion
(7) Very little smoke
(8) Relatively long life

Disadvantages

(1) Weight per horsepower fairly high
(2) Comparatively slow speed
(3) Comparatively large radiator for cooling
(4) Difficulty in throttling to less than one-half speed
(5) Slow acceleration
(6) Not enough flexibility

The point has been brought out that the engineering on the Diesel engine is very far behind that on the motor-vehicle engine. I think that any one who is familiar with what has been done in the last few years certainly will not agree with this. I believe the Diesel engine is just about as satisfactory, for the uses for which it is intended, that is, for heavy-duty powerplant service, as the motor-vehicle engine is for motor-vehicles. The changing of a Diesel engine to become a flexible high-speed engine is a comparatively new idea and will necessitate a great amount of research and inventive ability for its accomplishment; but, so far as the engineering is concerned, motor-vehicle engineers can learn many things from the Diesel engine. One instance is the careful way in which the throws of the crankshafts on two, three, four, and six-cylinder engines have been counterweighted. Another is the fact that the majority of Diesel engines have the piston-pin near the center of the bearing-surface of the piston, which prevents piston-slaps.

Recently, I read in the operation book of a Diesel-engine company the following paragraph:

> If the piston-head accumulates a lot of carbon, the compression is too low; injection-air pressure is low; or else, an excessive quantity of lubricating-oil is being used.

This is a very frank statement and is the type of statement which probably we would get today from automotive engineers. Until recently the automotive engineer was trying all types of lubricating-oil and condemning the oil when he got too much carbon on the top of the piston. Some of this has been the fault of the oil, but most of it has been due to poor combustion, the shape of the combustion-space, the intake-manifold, and a number of other things. Or else, in the case of the oil, it has been due to its being thrown off in too great quantities by the connecting-rods or by some wrong feature of design of the pistons and piston-rings. Such things make me believe that the Diesel engineers are fully capable of looking after their own design. However, automotive engineers probably can be of some assistance in helping to develop these engines into the type which would be satisfactory for motor-vehicle work, provided there is sufficient demand for engines possessing the very desirable requirement of economy of operation. The present trend does not seem to be in that direction.

[4] See The Journal, February, 1927, p. 212.
[5] M.S.A.E.—Consulting engineer, Indianapolis.

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Two Desirable Quiet Driving-Ranges for Automobiles

By THOMAS L. FAWICK[1]

MILWAUKEE SECTION PAPER *Illustrated with* PHOTOGRAPHS AND DRAWINGS

ABSTRACT

REFERENCE is made by the author to a quiet driving-range for both light and heavy traffic and another quiet range suitable for driving over paved roads where low engine-speed and fast car-speed are of vital importance to satisfactory performance. His argument is that engine-speeds must be reduced to secure maximum economy, long engine-life and comfort. He asserts that smoothness and quietness of operation at high speeds are the most outstanding incentives for using a quiet fourth-speed gear-combination. Cars equipped with a fourth speed of the type he describes are driven from 80 to 95 per cent of their total mileage while operating in the higher ratio. This of course requires that means must be provided for shifting easily from fourth to third speed or from third to fourth speed.

With regard to the four-speed transmission-and-axle combination described, this is a small transmission unit having a bell housing in which there are no countershafts and no idling gears when in direct drive. The unit is a distinct two-speed-forward-and-reverse transmission incorporating a clutch shaft-gear or sun-gear, three planet-gears and a longitudinally movable gear which can be set in low, in reverse, in direct, or in neutral position. The transmission is arranged with two gearshift shafts, the second shaft to be arranged for shifting the two-speed rear-axle ratio-changing device. This provides four speeds forward and two in reverse.

For the six-speed transmission internal-gear overdrive, the author states that the internal gear can be left in mesh with the clutch socket of the internal gear or with the internal gear. When left in direct engagement, the transmission is operated as a standard conventional three-speed unit. If the auxiliary lever is shifted to place the pinion in connection with the internal gear, then each of the first, the second, the third and the reverse ratios is stepped-up to be 1.29 to 1.00.

The discussion emphasizes that proper lubrication is important. The prevention of warpage when producing the gears and the precautions taken to make the gears concentric are also discussed.

MUCH greater comfort and less operating cost for the faster driving-ranges of automobiles are inevitable. Many attempts have been made to obtain a practicable fourth-drive. Automotive engineers are too familiar with this endeavor to necessitate reviewing the history of the spur-gear fourth-drive and the double-bevel-gear axle. The spur-gear fourth-drive is too noisy to be given further consideration, to say nothing of its inefficiency and short life. The double-bevel-gear axle presents a real manufacturing problem. While it may be possible to make them quiet, I believe it is a proved fact that the cost is prohibitive. However, two quiet-driving-ranges are now within the range of possibilities without undue cost to the motor-vehicle manufacturer. In this paper, my purpose is to describe some of the designs and devices worked out in an effort to promote the idea and desirability of building into motor-vehicle construction means for obtaining these quiet driving-ranges; namely, one quiet driving-range for both light and heavy traffic, and another quiet range suitable for driving over our constantly increasing mileage of paved roads where low engine-speed and fast car-speed are of vital importance to what may truly be called satisfactory performance. Some persons will never care to drive at a speed of more than 30 to 35 m.p.h., but they are few.

For all practical purposes, a properly built fourth-ratio eliminates engine vibration. When an engine operates at the right speed for country driving, a driver can travel as fast as it is practicable to drive and will notice no engine vibration. When coasting down-hill, many drivers throw out the clutch to coast down and then let the clutch in again but, in driving some 30,000 miles through the over-gear, I left the clutch in and I have never noticed any engine vibration.

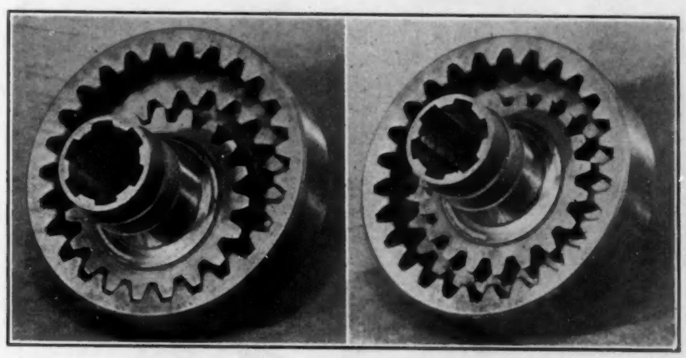

FIG. 1—INTERNAL OVER-DRIVE GEAR
The View at the Left Shows the Gears in the Over-Drive Position. At the Right, the Gears Are Shown in the Position for Direct Drive

The most expensive luxury tolerated by the motor-car buyer is the thoroughly inadequate inefficient three-speed transmission, which materially shortens the life of exceptionally well-built engines and soon ruins their quality of quiet operation. The public will save millions in fuel and in car-wreckage costs by use of a quiet and efficient fourth driving-range.

REDUCED ENGINE-SPEED

Engine-speeds must be reduced to secure economy, length of life and comfort. Most of the experiments I have conducted on internal gearing have been in connection with Cadillac and with Dodge cars. I have driven a Cadillac Model-61 car about 30,000 miles through internal gearing, such as is shown in Figs. 1 and 2. The experimental work along this line has been extremely

[1] M.S.A.E.—Racine, Wis.

interesting from many different angles. From my experience with a car of this kind, I conclude that the smoothness and quietness of operation at high speeds is the most outstanding incentive for using a quiet fourth driving-range.

The component parts of the internal over-drive gear designed for the Cadillac Model-61 car are shown in Figs. 1 and 2. We have installed this unit on a number of Cadillac Model V-63 cars as well. In Fig. 1, the view at the left shows the gears in the over-drive position, that at the right showing the gears in the position for direct drive. Fig. 2 illustrates the general assembly.

Although it is well known that the new Cadillac cars operate very smoothly, it is surprising how much more quietly the car operates at high speeds when the engine-speed is considerably reduced. The internal gear in this unit has 26 and the pinion has 19 teeth. If the axle ratio is $4\frac{1}{2}$ to 1 when in direct drive, the ratio is reduced to 3.28 to 1.00. To give an idea of how extremely important it is to have exactly the right ratio between the third and the fourth driving-ranges, we tried both 18 and 20 teeth for the pinion, leaving the internal gear at 26 teeth. With 20 teeth in the pinion, we found there was not enough spread in ratio to get the best results with the Cadillac engine. It had ample power for a slightly greater spread of ratio. Using 18 teeth for the pinion, however, made the car somewhat sluggish, and the pick-up and get-away were not entirely satisfactory. The 19 to 26-tooth combination seemed to have exactly the right balance for a car of the weight and power of the Cadillac. This ratio is 1.38 to 1.00.

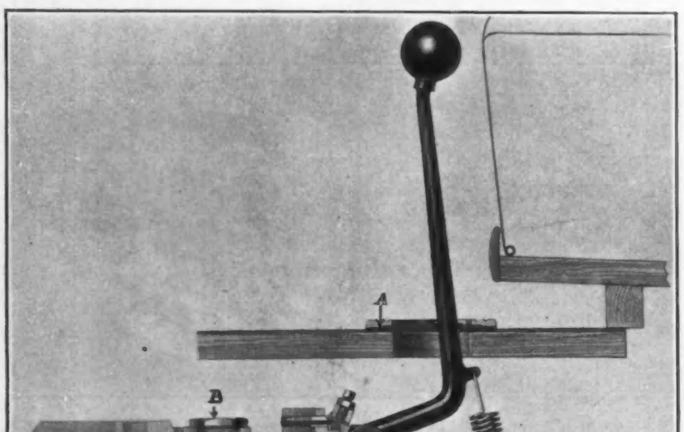

FIG. 2—GENERAL ASSEMBLY OF THE OVER-DRIVE UNIT

The Internal Gear in This Unit Has 26 Teeth and the Pinion Has 19 Teeth, Which Seems To Provide Exactly the Correct Balance. The Light Shading Indicates the Transmission Case of the Car. The Speed-Range Gear Is Indicated by Dark Shading. An Air-tight Floor-Plate Is Located at *A*, an Oil-Plug at *B*, a Drain Plug at *C*, and the Speedometer Drive at *D*. Felt Packing, Located at *E* and at *F*, Assures Individual Lubrication for the Speed-Range Gear

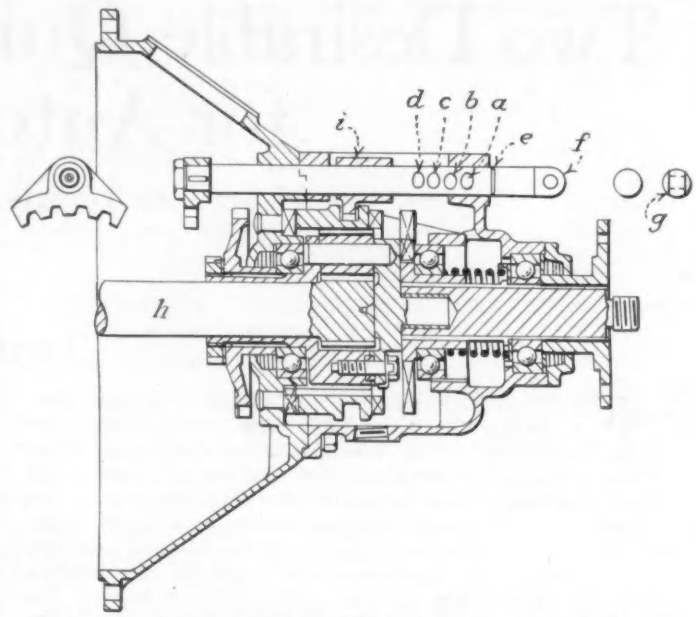

FIG. 3—PROPOSED FOUR-SPEED TRANSMISSION-AND-AXLE RATIO-CHANGING MECHANISM

In This Combination Construction, No Countershaft Holes Are Made in the Transmission Housing. There Are No Extra Gears for Reverse, Although Reverse Drive Is Available in Two Different Speeds If Desired, Which Makes a Total Range of Six Speeds Available. Low, Neutral, High, and Reverse Shifts Are Indicated at *a*, *b*, *c*, and *d* Respectively. The Location of Shift-Rod No. 1 Is Indicated at *e*, and That of Shift-Rod No. 2 at *f*. The Rod Indicated at *g* Is for Shifting Ratios in the Two-Speed Axle. The Clutch Shaft Is Indicated at *h*. The Cross-Hatched Part Indicated at *i* Is Keyed to the Rod

While the 1.38-to-1.00 ratio worked-out exceptionally well for the Cadillac, in bringing out a unit for Dodge cars we found that an entirely different ratio was necessary. The ratio finally determined upon was 1.29 to 1.00. In both cases the ratio provides ample hill-climbing ability. If hills are approached at a fairly high speed, as is usual in country driving, it is surprising how easily the car negotiates long and steep hills with its engine working at slower speeds and at maximum torque. In making numerous trips into Illinois, Michigan, Indiana, and Iowa, there was less trouble about negotiating hills in the over-drive than in the direct drive. This does not hold true, however, when it is a matter of climbing hills slowly or making a standing start on hills.

In starting on a trip, the auxiliary lever is usually shifted over to the higher range and left there indefinitely, making the start from low into second and into high-speed through the internal gear just the same as if no over-drive existed. This is merely a convenient device for accomplishing in a second of time the equivalent of changing the rear-axle gear-ratio. In this type of unit there are no idling internal-gears when running in fourth-gear. A gear of this type is practically a direct drive. If the step-up is 30 per cent, the gear would then be 70-per cent direct drive and 30-per cent tooth-roll.

OPERATING ECONOMY

Economy of operation and longer life of the engine are no mean advantages, coming naturally, as they do, with the use of a properly designed fourth-ratio. Numerous tests have disclosed that a gain of from 15 to 30 per cent in miles per gallon can be expected, and a considerable gain in miles per gallon of lubricating-oil is also accomplished. However, I consider the thrill of traveling at high speeds, as if coasting, of more value than the saving in fuel. In my opinion, a fourth-gear which reduces engine-speed and engine wear is indis-

pensable, even though no saving were made in fuel consumption.

Not long ago cars were sold to operate within limited territory, under more or less local conditions. Today, cars are sold to operate in all parts of the world. It is not unusual for a car sold in New York State to be driven across the United States to points on the Pacific Coast. Hence, a car geared properly to travel over bad roads and hills is not best adapted for comfortable driving over the thousands of level and slightly hilly roads now available for motor-vehicles.

Motor-cars equipped with a properly designed four-speed transmission have ample flexibility for negotiating any conditions encountered. Our experience is that cars equipped with a fourth-speed are driven from 80 to 95 per cent of their total mileage in the higher ratio, and means must be provided for shifting easily from fourth to third or from third to fourth-speed.

In some of our earlier designs it was necessary to use an extra gearshift lever for operating the auxiliary gear. At first thought it seems that an extra gearshift lever would be objectionable and more or less in the way of the driver; but that is not entirely true, although I believe that when a complete fourth-speed transmission-unit is manufactured on a production basis it is imperative that it should all be operated by a single control-lever. I think it would not be good practice for any car builder to bring out a new car equipped with two levers.

The accompanying illustrations show designs which may be worthy of consideration as a means of obtaining two quiet driving-ranges. All but Figs. 3 and 4 show the over-drive or fourth-gear incorporated in the main transmission-case. I believe that over-drive is commonly understood to be the fourth ratio, or driving-range, regardless of whether the transmission operates through an internal gear on third or fourth ratio. Several of the illustrations show a transmission which is of the conventional type, except for the double internal-gearing and clutching mechanism adjacent to the clutch. A distinct advantage of having the internal gearing located at this point is the fact that it will only be called upon to transmit direct engine-torque.

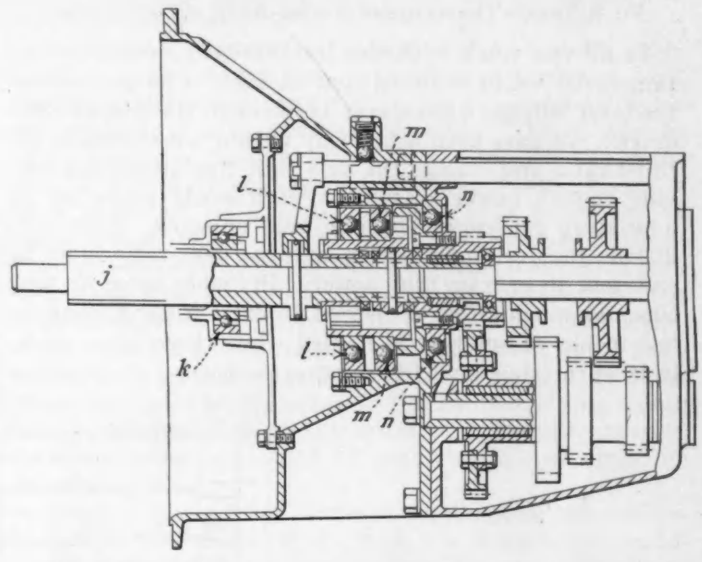

FIG. 5—FOUR-SPEED TRANSMISSION WITH DOUBLE INTERNAL-GEAR
The Double Internal-Gear Is Used Adjacent to and As a Part of the Clutch Shaft *j*, the Bearing of Which Is at *k*. Two Standard Ball-Bearings, *ll* and *mm*, Carry the Second Driving-Pinion, Which Meshes with an Internal Gear Mounted on the Ball-Bearing Shown at *nn*. The Internal Gears in This Construction Are in Constant Mesh, Having a Jaw Clutch-Shifting Element between the First Driving-Pinion and the Driven Internal-Gear To Facilitate Shifting at High Speeds

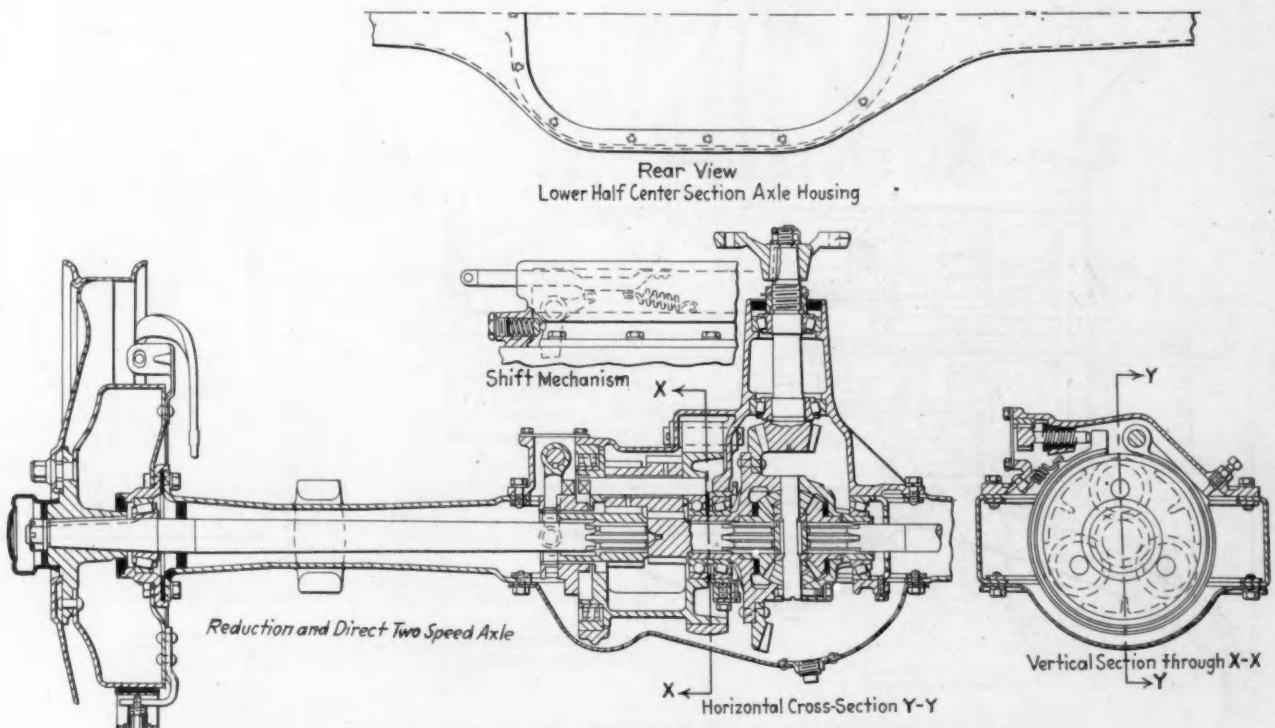

FIG. 4—ASSEMBLY VIEWS OF THE TYPE OF CONSTRUCTION SHOWN IN FIG. 3
This Reduction and Direct Two-Speed Axle Is Designed for Trucks, for Which Quietness Is Not So Important As for Passenger-Cars. The Loads Being Heavy, the Reduction-Gear Unit Can Be Installed Near the Axle Drive-Pinion or Worm-Gear As the Case May Be. Also, the Reduction-Gear Unit Can Be Mounted Back of or Ahead of the Transmission. At the Top of the Illustration Is Shown the Rear View of the Lower Half of the Center Section of the Axle Housing. The Central Insert Shows the Shift Mechanism. A Vertical Cross-Section through *X-X* Is Shown in the Lower Right View, and at the Right End of the Axle Is a Horizontal Cross-Section through *Y-Y*

Four-Speed-Transmission-and-Axle Combination

In all our work with the internal-gear over-drive arrangement we have found that as high as 98 per cent of the total mileage driven may be through the higher-ratio drive. We have been asked why we did not eliminate the third ratio and change the axle; but that would not provide enough power to pull through sandy roads, or up long steep grades, or through mud or snow. Such conditions require ample power, and the gear-ratio must be sufficient to provide that power. Probably three or four times as much effort is needed to drive a car through a few inches of snow as is needed when there is no snow. It is surprising how little power is needed to propel a heavy car at speeds of 40, 50 and 60 m.p.h., if it is equipped with the right gear-ratio. That is what makes it so detrimental to the engine because, when the car is running at high speeds, the engine is not working sufficiently hard. I have driven the Cadillac car referred to time after time at 70 and 75 m.p.h. and, even at such speeds, one could hardly tell that there was an engine in the car. I put the over-drive gear on the new V-63 model, a car that is a masterpiece for quiet operation and that has a wonderful engine. Even with that degree of quietness, when traveling at the higher speeds, and a shift is made into the over-drive, it is just as though the engine fell out of the car and as if the car were coasting. As I have said, I consider that sensation of just coast-

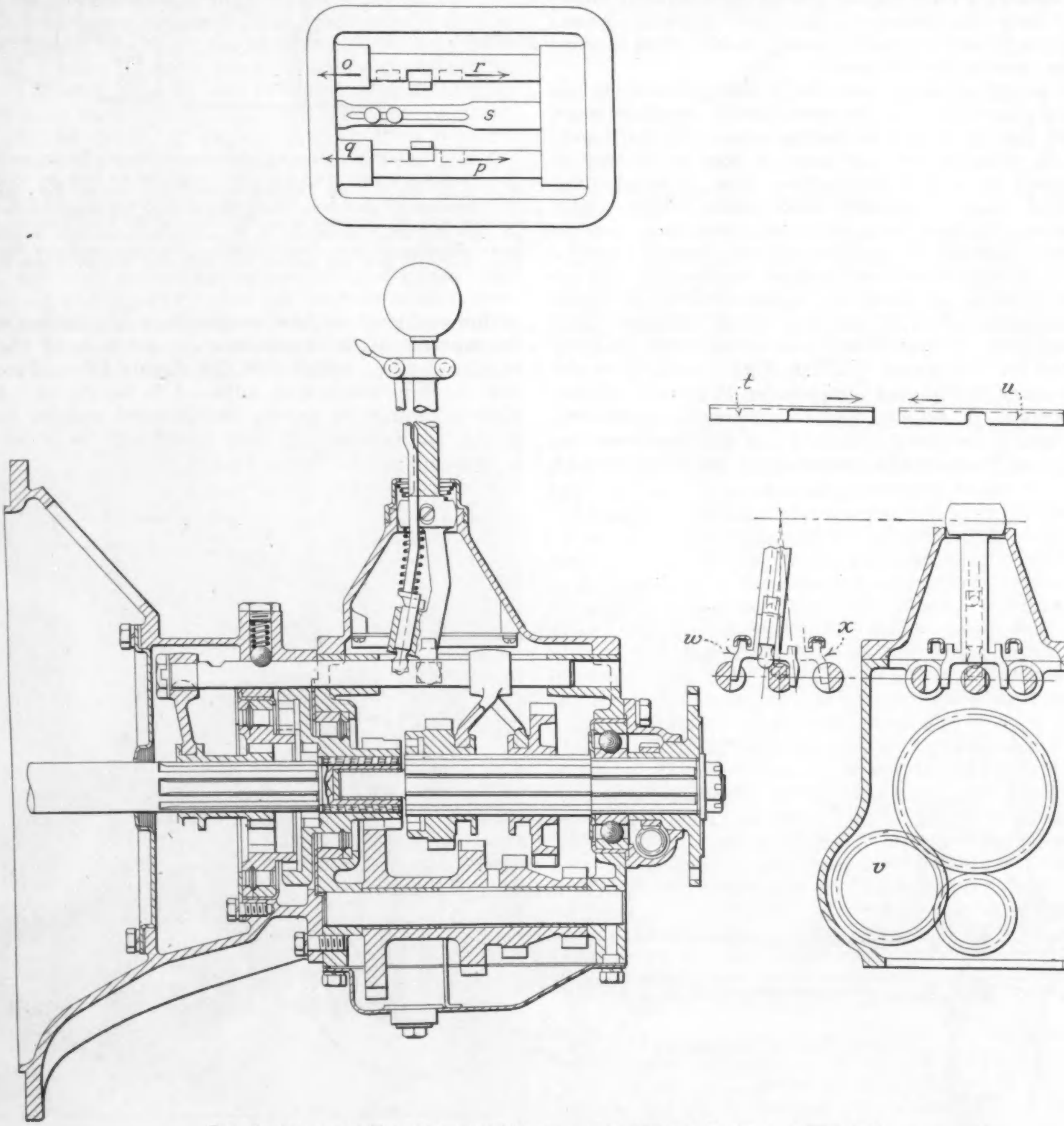

Fig. 6—Assembly Views of the Four-Speed Transmission Shown in Fig 5.
The Upper Left-Hand Drawing Is a Top View of the Gearcase, Showing the Arrangement and Operation of the Gearshift Rods. These Are Located at *o*, Low-Speed; at *p*, Second-Speed; at *q*, High-Speed; and at *r*, Reverse. The Location of the Speed-Range Gearshift Is Shown at *s*. The Direction of Motion of the Gearshift Rods Is Indicated by Arrows. The Lower Left View Shows the General Assembly. In the Upper Right View, the Left-Hand Gate for High and for Second-Speeds Is Shown at *t*, and the Left-Hand Gate for Low-Speed and Reverse Is Shown at *u*, the Location of the Front of the Transmission Being Indicated by the Arrows. The Position of the Reverse Idler-Gear Is Shown at *v* in the Lower Right View. The Second-Speed and the High-Speed Positions of the Gearshift Lever Are Shown at *w* in the Central View; and the Low-Speed and Reverse Positions of This Lever Are Shown at *x*

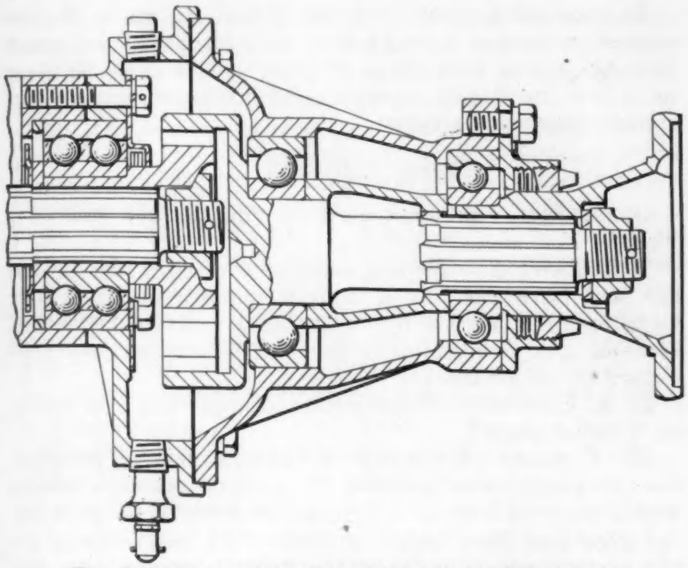

FIG. 7—INTERNAL-GEAR PERMANENT UNDER-DRIVE UNIT
The Reduction in This Unit Is 1.29 to 1.00, and It Is Used To Replace Very Large Reduction Axles. It Is Especially Useful Where Very Low Ratios between the Transmission-Shaft and the Axle Are Required

ing along at high speeds of more value than the quantity of fuel or of cylinder oil that might be saved. These are small items; although, taken as a whole, if all cars in the United States were equipped with over-drive gears and used, as records show they are used, 70, 80 and 90 per cent of the time, the saving in fuel consumption throughout the entire Country would in the aggregate be an enormous quantity and would amount to millions of dollars per year.

The type of construction shown in Figs. 3 and 4 lends itself favorably to quantity production at moderate cost. In this combination construction, no countershaft holes are made in the transmission housing. There are no extra gears for reverse, although reverse drive is available in two different speeds if desired, which makes a total range of six speeds available. No gears are in operation in either of the two higher driving-ranges; that is, there are no idling gears in the transmission and, therefore, it is noiseless. This combination permits the highest ratio to be direct, which allows a better gear-combination for the ring-gear and the pinion, and a ratio which is more easily made quiet in operation. Shifting from one ratio to the other in the ratio-changing device can be accomplished at any speed with exceptional ease, as there is no possibility of gear clashing or stripping of gear teeth.

When shifting from fourth to third-speed, the positive clutch is first disengaged; then, the contracting band-brake stops the planet-gear carrier with ease. This band does not act as a brake as in the rear wheel of the car. It is merely a holding device, applied to take up the difference in inertia of the faster-moving parts from fourth to third-speed. Even though this device should be shifted continually with the clutch engaged, I believe no damage would be done. If desired, a positive clutch can be used for clutching either end of the ratio-changing mechanism.

For truck service, where a slight sound which may come from a gear unit of this type when operating at

FIG. 8—SIX-SPEED TRANSMISSION
The Internal Gear Can Be Left in Mesh with the Clutch Socket of the Internal Gear, or in Mesh with the Internal Gear. When in Direct Drive, the Transmission Is Operated As a Standard Conventional Three-Speed Unit. The Upper View Is a Section through X-X and Shows the Arrangement of the Reverse Gear and Shaft

high speed would not be considered a great disadvantage, it is possible to mount this unit adjacent to the driving-pinion either in a bevel-gear or a worm-gear drive. We have tested a unit of this type in connection with a Ford car, using dog-clutches at both ends. We found that it not only shifted with exceptional ease but that it could be shifted into either direct drive or reduction drive at speeds up to 30 m.p.h. without disengaging the clutch. There was no limit to the speed at which the shifting could be done successfully from under-drive to direct drive, even with the clutch engaged, although we do not recommend this as a general practice. It is proposed to use a single shift-lever for all speeds.

The axle differential and the speed-changing device are assembled on the differential-carrier housing, which is the usual practice for mounting a differential and ring-gear assembly. The banjo housing in this case is not enlarged, which diminishes road-clearance; it is merely elongated to permit the application of an enlarged differential carrier, thus permitting the usual assembly process for this entire unit.

Other Advantageous Features

A four-speed gear-combination such as this has another advantage due to the fact that all the gears except the internal gear are small in diameter. That is a very important point in manufacture. If a gear can be made small, say not over $2\frac{1}{2}$ in. in diameter, that reduces the cost of the material. A gear of that kind can be made on the new high-speed Fellows gear-shaping machines in about $2\frac{1}{2}$ min. After being put through the hardening process, they should come out within 0.001 in. of their dimensions before they were hardened. But that is not true of gears of 6 and 7-in. diameter. Many of these warp badly.

Very few bearings are used. This should facilitate the manufacture of a four-speed transmission in which the two higher ratios would be absolutely quiet and be a combination which could be manufactured at reasonable cost.

Figs. 5 and 6 illustrate a four-speed transmission using the double internal-gear adjacent to and as a part of the clutch shaft. In Fig. 5, two standard ball-bearings carry the second driving-pinion which meshes with an internal gear mounted on a similar bearing. In this case, the internal gears are in constant mesh and have a jaw-clutch shifting-element between the first pinion and the driven internal-gear to facilitate shifting when driving at high speeds.

Fig. 7 shows an internal gear permanent under-drive unit such as is used by one of the leading truck manufacturers to take the place of very large reduction axles. The reduction in this unit is 1.29 to 1.00. This type of unit is especially useful where very low ratios between the transmission-shaft and the axle are required.

Six-Speed Transmission Internal-Gear Over-Drive

Fig. 8 shows a six-speed transmission; that is, the internal gear can be left in mesh with the clutch socket of the internal gear or in mesh with the internal gear. When left in direct drive, the transmission is operated as a standard conventional three-speed unit. By mounting the pinion-shaft carrier on a continuation of the countershaft, the amount of sidewise movement in shifting from direct to over-drive is reduced to the minimum. This design facilitates especially easy shifting.

In conclusion, nothing could please me more in improved motor-car construction than to have two quiet driving-ranges, regardless of how that is done so long as it is a thoroughly practical and lasting means for accomplishing such a result.

THE DISCUSSION

QUESTION:—For what cars do you market your devices?

T. L. FAWICK:—We are marketing one for the Dodge car and have put out a limited number of units for Cadillac cars. We are building this permanent reduction internal gear continuously for one of the largest producers of motor-trucks.

E. A. COUSINS[2]:—What pressure angle are you using on internal gears?

MR. FAWICK:—It depends on the ratio wanted between the two gears. For instance, if the ratio becomes one in which there is only a difference of four teeth between one gear and the other, it probably will be necessary to use a steep pressure-angle, say around 28 deg. In the Cadillac unit we used a 26-deg. pressure-angle. Otherwise it is just a standard 6 to 8 pitch. On a job of that kind a full-length tooth cannot be used because there is too much interference and they would not operate together.

MR. COUSINS:—We had experience with several jobs in which there was a difference of four teeth, and we used a $27\frac{1}{2}$-deg. pressure-angle.

MR. FAWICK:—The Cadillac unit has a $22\frac{1}{2}$-deg. pressure-angle. We were able to accomplish that because we have a difference of seven teeth. That gave us a little more speed and a chance to decrease the pressure angle. In an internal-gear job, I think it is always best to keep the pressure angle as low as possible. If you could use a 14-deg. pressure-angle, that would be much better.

A. C. WOLLENSAK[3]:—How are the internal gears cut? The full teeth seem to run right back to the end.

MR. FAWICK:—The internal gears are cut on a standard Fellows gear-shaping machine. It may seem that the full teeth run down to the end, but they do not; they run full to within $\frac{1}{8}$ to 3/16 in. of the end.

CHAIRMAN W. S. NATHAN[4]:—What special precautions are taken in lubrication? Have you had experience with noise due to cavitation of the oil?

MR. FAWICK:—We have had some trouble with noise in some of the eccentric units; that is, on the units in which we put on an attachment and used the eccentric for shifting from one position to another, we have had some difficulty due to oil leaking out. If the oil gets down below the internal gear the sound from the gear changes and, if the oil gets down that low, it is time to put more oil in. That is one reason that we designed a newer type for the attachment, using the shorter shift in which we do not use the eccentric. In that unit it is much more practical and carries the oil without so much leaking. It is not unusual to run 3000 or 4000 miles on one oiling. Oiling is very important. The devices must be oiled or they certainly will make a noise and wear out sooner than they would otherwise.

We had one job in a motorcoach that had run probably 40,000 miles; it ran well until someone forgot to oil it. The vehicle ran to a total of 50,000 miles, and then they sent the gears back to us. The gears were blued and showed that they had generated heat. After they installed another set of gears and oiled them properly, they had no further trouble. The same motorcoach-operating company installed 15 or 20 of the units, de-

[2] M.S.A.E.—Sales engineer, Hyatt Roller Bearing Co., Detroit.
[3] M.S.A.E.—Chief engineer, Sterling Motor Truck Co., Milwaukee.
[4] Jun. S.A.E.—Service department, Nash Motors Co., Kenosha, Wis.

manding the internal gear. The drivers became accustomed to the over-drive gear and the smooth operation at high speed. They found that the greater economy and greater comfort in driving was worthwhile.

MR. COUSINS:—On the transmission attached to the Cadillac, the ball bearing seems to slide with the shifting of the gear. How much clearance do you allow between the outer race of the ball-bearing and the housing?

MR. FAWICK:—We have it keyed so that it cannot revolve. We tried about 0.001-in. clearance, which worked well if the vehicle ran slow. If it ran a distance of say 40 to 50 miles at high speed, the bearing would get warm enough so that it would expand and, when we tried to shift it back, it would not shift. We eliminated any possibility of sticking by giving it from 0.0015 to 0.0020-in. clearance.

MR. COUSINS:—Was there any chatter?

MR. FAWICK:—No. We discussed that subject with the ball-bearing manufacturers who said that they were afraid the outer race might get cocked and cause trouble. We built a unit and put the bearing up close to the pinion, where it would take the full load and keep the shaft and pinion in place. We put the key in the first one to hold the outer race from turning. There is no trouble encountered from sliding the bearing. It slides and shows no wear.

MR. COUSINS:—Is that the job in which you use the lower pressure-angle so that the bearing load is not so great, and there is no chance of breaking down the oil-film? There would be an oil-film between the outer race and the housing. Was the load not great enough to break it down, and is that why you got satisfactory results?

MR. FAWICK:—That would make no difference. We have tried a 26-deg. pressure-angle and also a 22½-deg. pressure-angle. It is a No. 309 bearing.

A MEMBER:—You mentioned pulling the pinion out, sliding it completely back and then turning it on the eccentric and meshing it in on the end of the teeth. What is the reason that you cannot mesh it directly in like a tumbler-gear?

MR. FAWICK:—With the pinions dropped in edgewise, if you try to pull them out the other way they will move out say 1/16 in. and then there will be interference. The gear will not slide in any other way but endwise.

MR. WOLLENSAK:—What precaution do you take to hold the internal gears concentric? Do you use hardening dies to prevent warpage during hardening?

MR. FAWICK:—We have had no trouble on that score. What we have done is to take our forgings as they come out of the hammers and normalize them and have the forgings made without an excessive amount of stock on the outside; then the forgings are machined completely, leaving grinding stock for bearings. Many gears are made by centering them according to the pitch-line, but we disregard the pitch-line. We have the outside of the gear running absolutely true when it is in the gear-shaping machine and, before the gear is hardened, we know the pitch is true with the outside. We harden the gear and true it up on the grinding-machine according to the outside diameter. We used to true it by the pitch-line, but we had more trouble that way. In grinding the bore and truing it up in relation to the outside we found practically no difficulty. As to warping out of shape, on gears of the sizes we have used in the Cadillac unit, we very seldom found any that warped 0.001 or 0.002 in. That much difference on an internal gear is nothing to worry about, and we never notice the difference. We have a job in which we used crocus and oil on a Gleason running-in machine. We use a reversible motor so that we can put the pinion into the internal gear, run it in one direction under a slight load and then reverse the motor and run it in the other direction. That gives the teeth a fine polish and corrects any slight errors in the spacing of the teeth which may develop either in cutting or in the hardening, provided the error is not too great. In doing that, we found that running it about 5 min. was equivalent to 500 miles of operation on the road. Many gears would run absolutely quiet at the start at almost any speed. Occasionally we get a gear that makes a slight noise up to 35 or 38 m.p.h. and then becomes absolutely quiet. Almost any of the gears would be considerably improved by running-in with crocus and oil first.

QUESTION:—Have you made any test on a pair of these gears to determine the mechanical efficiency approximately when running them together under these loads? The success of the whole idea seems to me to depend on what the gears will do as regards the power-loss.

MR. FAWICK:—Even though the loss of power of the internal gear were 5 per cent, I believe that does not mean much. The numerous tests we have made show from 15 to 30 per cent more mileage per gallon of gasoline through the gear than you can get on the direct drive. The efficiency of the internal gear is much closer to 100 per cent than almost any other type of gear.

MR. COUSINS:—I am familiar with a number of developments in passenger-car drives, and all of them are direct in fourth with the internal-gear reduction in third. You seem not to favor that design. What are your opinions pro and con on each type?

MR. FAWICK:—My opinion is that with four speeds and two driving-ranges, one for city driving and one for country driving, the driving must be quiet. I would not buy a car that makes any gear noise in third-speed and is quiet in fourth-speed. It must be quiet on both driving-ranges. I would rather have more sound on the fourth-speed where there is no engine sound than to have some noise on third when there is also sound from the engine. If driving through internal gears on third and direct on fourth, it is all right if it is possible to get them so that there is no sound; but the characteristic of the internal gear is to make slightly more sound at low speeds than at high speeds. We found that in every case we got sound out of the internal gear at car speeds from 18, 20 to 35, and 38 m.p.h.; when we traveled at greater speed, that sound disappears. The number of gear teeth in the pinion and in the internal gear has something to do with the tone of the gear.

MR. COUSINS:—As to lubrication, do you use an oil-pump?

MR. FAWICK:—The job is designed so that an oil-pump is not needed. The internal-gear transmission speed-change device was developed in Racine, Wis. We developed it and later it was taken up by other companies. Some of the transmission companies are now offering four-speed transmissions to the trade. They are using the internal gear.

MR. WOLLENSAK:—Referring to the step-up gear, considering a car with three-speed transmission, it is well understood that, on direct drive, there is enough power to take that car up a fairly steep incline on direct drive. Is not the practical procedure to put the step-up gear on the fourth speed so that on a level road there will be increased speed with less gasoline consumption?

MR. FAWICK:—Yes. That is one of the main objects of the whole idea; it is to get quiet operation, low engine-speed and greater efficiency for any motor-vehicle, whether of the passenger or of the commercial type.

MR. WOLLENSAK:—There seems to be some question as to whether the internal-gear drive should be on the fourth speed.

MR. FAWICK:—I consider that it is not an important factor so long as the drives are quiet. We made them both ways. In the paper[5] by C. A. Neracher and Harold Nutt, it was admitted that they did get some sound on third speed when driving through the internal gears. S. O. White, chief engineer of the Warner Gear Co., likewise said that they had some sound on third speed from the gears. My contention is that the public will not tolerate any sound when driving in third gear. I further contend it is unnecessary to have any sound. I think that third and fourth speeds should be noiseless.

[5] See THE JOURNAL, February, 1927, p. 247.

SCIENTIFIC TRANSPORTATION

(*Concluded from p.* 81)

new transportation "tool," as they call the motorcoach. I should like to suggest that each of you try to mold public opinion so that the railroads will be allowed to use this tool when they wish to do so. Mr. Scarr has been trying for some time to use motorcoaches in Pennsylvania. The Philadelphia & Reading Railroad, also in Pennsylvania, and the Baltimore & Ohio Railroad, in West Virginia have had the same experience. No matter how willing we may be to use them we are not allowed to do so without a great struggle.

There are two sides to the question. If each of you would try to mold public opinion, and if public officials would appreciate the fact that the railroads are the transportation agencies and should give the service if it is desired, that might help facilitate the solution of the problem.

MR. SCARR:—This discussion has been based principally upon what might be termed a "through-movement" basis of using the container, and on that basis I firmly believe in its future great possibilities. My belief is based upon certain definite fundamentals. Between Philadelphia and New York City the equivalent of approximately 400 carloads of freight per day is moving over the highways. That means approximately 2500 tons of freight and represents, at our average rate for third-class freight, approximately $5,000,000 a year in revenue. This is but one instance, on one road.

A fair proportion of that traffic will continue on the highways because a specialized service is required. It costs between $0.40 and $0.60 per mile to move a 5-ton body on rubber, while in the form of some container it would cost a much smaller sum to move it by rail. The final outcome will be a compromise between the low cost of line haul on the railroad and the high cost of line haul on the highway, and that means a big future for container operation.

CHINA

PRACTICALLY every civilized nation on earth has its representatives in China, all trying to get a foothold on the soil that is today no less picturesque than it was 500 years ago and whose markets, cities, and ports have lost nothing of the magic ring.

In China agriculture is the dominant urge of the people. Today only 650,000 square miles or 15 per cent of the land is tilled. The wide range of climate, the rich soil and the simple wants of the people make China one of the few countries of the world that can, under normal conditions, be self-supporting. China is the wealthiest of Eastern countries in point of natural resources. Coal and iron, the foundation of modern industry, are plentiful there. Yet she produced in 1920 but 25,000,000 tons of coal, most of which was mined in Chihli province and in Manchuria, as compared to 650,000,000 tons mined in the United States in the same year. The problem is one of transportation. What is said of coal is also true of iron, which is found in almost every Chinese province, though worked in only a few districts on anything resembling an extensive scale.

The simple industrial system still continues in the inland parts of China, but in the big cities, such as Shanghai, Hankow, Canton, and Wusihu, the widespread use of modern industrial power is quickly relegating into the background the old domestic system. The country has just entered upon the industrial revolution which transformed the West 150 years ago. The old guild organization, binding everyone from merchant to craftsman, is now taking the form of craft guilds, the basis of labor unions. Contact with the West and the resulting clashes have stimulated a national feeling and the sweeping away of age-old systems. During the World War, many of China's foreign markets were closed to her. She was compelled to find means to furnish herself with what she needed. Factories and cotton mills sprang up. Great impetus was given to the industrial life of the nation. Presumably China will always remain largely agricultural, chiefly interested in the production of the things she excels in, such as tea, silk, raw cotton; but, to maintain her economic independence, to prevent famines, to support her teeming millions, she will have to develop herself industrially.

Foreign trade in China was begun centuries ago, in the year 166 A.D., when representatives of the Roman Empire introduced Chinese teas and silks to the Western world. Greeks, Persians, Arabs, Portuguese, Spaniards, and English all journeyed in the bygone days to share in the lucrative trade with China. America is the newest of arrivals in her midst. The value of China's total net imports for 1922 was almost 15 times that of 1874. In 1874 the value of the total exports of China amounted to only one-fourth of that of 1922. China is the biggest market in the world for cotton yarn, and the second biggest for cotton piece goods, the first being India. Ninety per cent of all cotton piece goods, both plain and fancy, comes from the mills of England, Japan and the United States. Great Britain leads, with the United States a strong second.—A. A. Young in *Trade Winds*.